T·H·E EARTH'S RICHES

***Copper** is extracted by roasting the ore in a furnace. The work is dirty and dangerous, so the men wear heat-resisting coats when the molten metal is cast into ingots.*

ZEFA

A ROYAL CROWN, A GOLD-plated mascot on the front of a Rolls Royce, ingots stacked in the vaults of a bank — wherever it crops up, gold symbolizes wealth and power because of the huge effort required to find it and extract it from the earth.

Gold is one of the most highly prized of all metals and, for this reason, it has always been used to mint coins. Gold also gives value to paper notes – in theory, these can be swapped for gold.

Unlike most metals, gold does not react with other common elements such as oxygen, sulphur or carbon. This is why it is known as a 'noble' metal. For the same reason, gold is found in nature as a pure metal rather than as a compound.

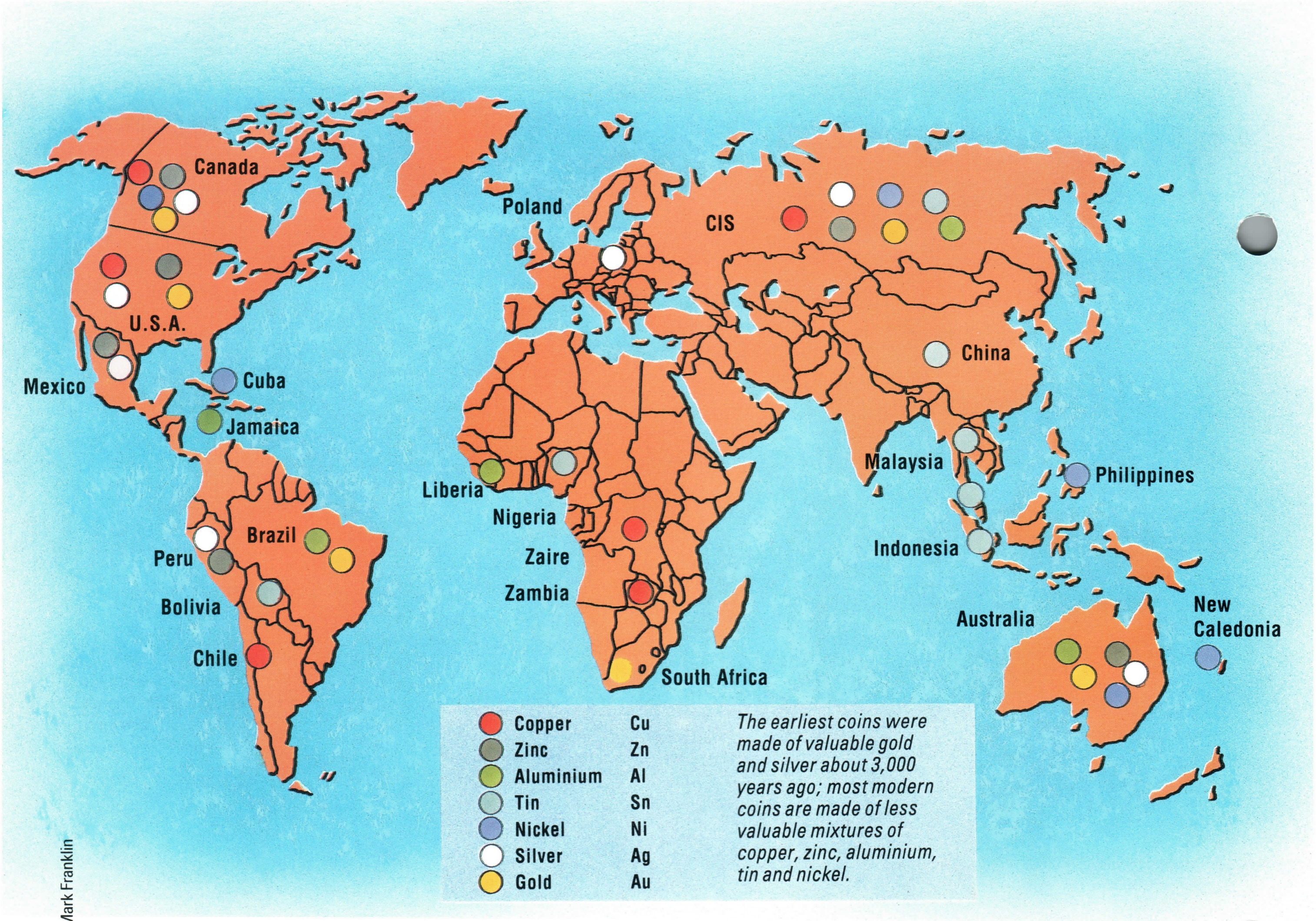
Most particles or nuggets are found in veins of quartz deep within hard, crystalline rocks, such as granite and solid quartz rock. They are also found in deposits of sand and silt washed out of quartz veins by running water. This is known as alluvial gold and is often found along the beds of streams and rivers.

Hard rock mining

Gold is found in lots of places around the world, but only a few countries have enough to support a gold mining industry (see map overleaf). The gold-bearing rock is usually extracted by underground mining in hard rock, often at great depths. Thus the Western Deep Levels mine at Carletonville, South Africa, is the deepest mine in the world, extending 3,777 metres down. At the lowest level of the mine, the temperature is 55°C.

Alluvial gold is extracted by dredging gold-bearing silt from the bottoms of lakes, or by using high pressure water jets to wash deposits out of the sides of hills. In some countries – Brazil, for instance – individual prospectors and

***Miners** start work by drilling deep holes in the rock that contains the ore they want. Explosive charges are placed in the holes and everybody is cleared out of the mine before they are fired. The rock is broken into pieces, ready for loading.*



The earliest coins were made of valuable gold and silver about 3,000 years ago; most modern coins are made of less valuable mixtures of copper, zinc, aluminium, tin and nickel.

miners extract alluvial gold by washing and sieving gravel from the beds of rivers by hand. Gold miners in the old Wild West used this method of mining.

Today, gold is only used as everyday currency in remote parts of Arabia, where normal coins are unknown. Special golden guineas are minted by the Bank of England and exported directly to these areas. Large quantities of other gold coins, including the Kruggerrand from South Africa and the Maria Theresa thaler from Austria, are still minted for people who want to buy gold as an investment instead of, say, shares.

Silver is the only precious metal still used in ordinary coins but even this practice is restricted to a few rich countries, notably Germany and Switzerland. Most silver is now obtained as a byproduct during the production of other, cheaper metals, such as copper, zinc and nickel. The ores of these metals contain small amounts of silver, so when electrolysis is used during copper or nickel refining, silver settles into the sludge of impurities that settle at the bottom of the tank. This sludge can then be further refined to recover the silver.

***Seven metals** are used for making coins. Ores from mines are usually processed in Western Europe or America to extract the metals.*

PURE GOLD

Pure – 24 carat – gold is so soft that it is not even strong enough for making jewellery. To give it more strength, gold is nearly always mixed with other metals like copper. For example, American golden dollars contain 10 per cent copper.

The purity of gold is normally measured in carats. If a ring were made of nine carat gold, nine parts out of 24 would be pure gold. The purest gold normally used for making jewellery is 22 carat, which is 22 parts pure gold out of 24.

Besides ornamentation, gold has many industrial uses. In fact, 10–15 per cent of world gold production is used in this way. One of the commonest uses is in electrical switches – the contacts that conduct the electricity are often plated with gold. This prevents wear due to sparking because gold is too soft to make sparks.

Chemical extraction

Like gold, silver may be found in its native state, but Argentite silver ore is mined in a few places (see map above). The ore is first dissolved in a sodium cyanide solution, which produces a compound called


ZEFA

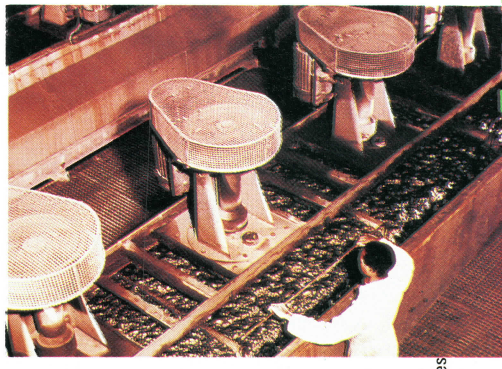
***Illegal gold** miners in Brazil work in terrible conditions to extract the bright metal. At Serra Pelada, they have dug the largest open cast gold mine in the world and they lift the gold-bearing rock to the surface on their shoulders. Elsewhere in Brazil, they use mercury to extract gold from river beds. This releases the poisonous metal into the river, killing miners and fish.*

Anglo American Corporation

***Hard rock** miners use pneumatic drills – similar to ordinary road drills – to bore the rock for the explosives.*

***To separate** metal ore from valueless rock, it is immersed in water. The ore rises to the surface and is skimmed off.*

***Hundreds of tonnes** of silver ore are crushed in revolving steel drums. Lumps of ore are flung against the sides by centrifugal force. The noise is ear-splitting!*



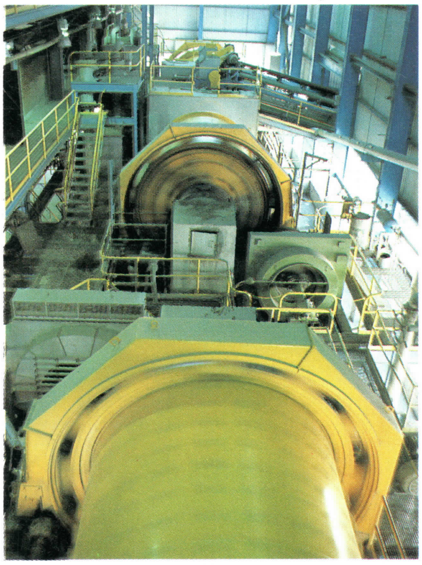
Camborne School of Mines

sodium argentocyanide. Zinc dust is added to this solution and the zinc combines with the sodium and cyanide because they are more reactive than the silver. This frees the silver from the compound and it sinks to the bottom of the tank.

A similar cyanide process is used to recover gold when the particles are too fine to be separated from silt or crushed rock by simply sifting or washing the unwanted material away.

Lots of silver is used industrially, particularly for photography and for making printing plates. When the films and plates are developed, a lot of silver is removed as waste. The waste is then passed through an electrical device that recovers the silver electrolytically. Silver re-cycled in this way is an important source of 'new' silver.

Most modern coins are made from the cheaper, more plentiful metals such as copper and tin – the 'base metals'. Among these, pure



David Leah/Science Photo Library

copper is occasionally found inside rocks and is known as 'native' copper. More commonly, it is found in ores in the form of copper sulphide (copper combined with sulphur) or, less often, copper oxide (copper combined with oxygen).

Rock containing the copper ore is obtained from opencast mines, which are like huge quarries, or dug out of mines. The ore-bearing rock is crushed in a ball mill by heavy rollers, each 6 metres in diameter, 7 metres wide and driven by a 5,000 horse power electric motor. After crushing, the copper ore is separated from the rest of the rock, at which point it is known as a concentrate.

Electrolytic copper

Copper sulphide ore is simply melted in a furnace to separate the sulphur from the copper. Oxide ore is dissolved in a tank of sulphuric acid, then the copper is extracted by electrolysis. Two copper rods (called electrodes) are lowered into the acid and an electric current is passed through the acid from one electrode to the other. Pure copper builds up on the negative electrode. Any impurities end up as a slimy sludge on the bottom of the tank. When the process is finished, the electrodes are lifted out of the acid, melted and then cast into ingots. Copper extracted in this way is known as electrolytic copper and is very pure.

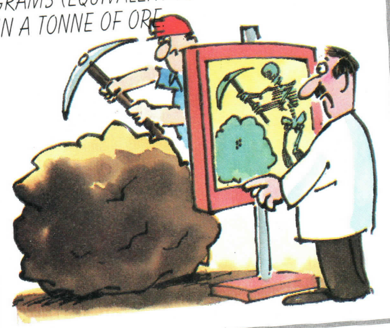
The most important zinc ore is zinc sulphide. Crushed zinc ore is heated in a furnace to convert the zinc sulphide into zinc oxide. Then the oxide is heated with carbon to remove the oxygen and produce pure zinc. The oxygen and carbon combine to form carbon dioxide gas, which floats away, leaving the pure metal.

The main nickel ore is nickel sulphide. As with zinc production, the first stage in producing nickel

Just amazing!

GOING FOR GOLD

A NEW X-RAY MACHINE CAN DETECT MINUTE AMOUNTS OF GOLD IN A SAMPLE OF ORE. USING HIGH SPEED ELECTRONIC CIRCUITS, IT CAN TRACE AS LITTLE AS 0.2 GRAMS (EQUIVALENT TO 20 GRAINS OF RICE) IN A TONNE OF ORE

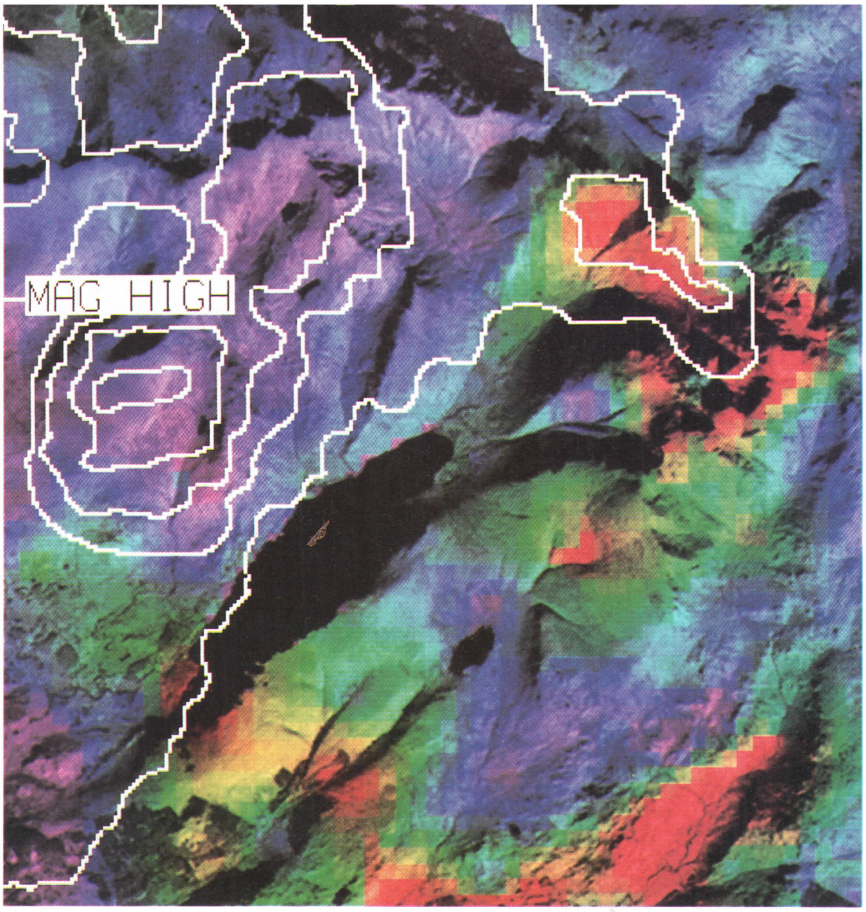


Paul Raymonde

SOLID GOLD SOUNDS

Ray Duns

Gold and silver records are normal vinyl discs with a thin coating of metal on the surface. For gold records, 24 carat gold is used; 'silver' records are coated with aluminium. A genuine copy of the hit record is placed in a vacuum chamber and given a negative charge of electricity. The metal is then vaporized and positive metal ions are attracted to the record's negative surface.



NRSC Farnborough

Satellite pictures, *enhanced by computer, can help to locate deposits of metal ore from the magnetic characteristics of the rocks. Here, tin ore is orange.*

from the mined ore is to heat it in a furnace to convert the nickel sulphide into nickel oxide.

A mixture of hydrogen and carbon monoxide gas, known as producer gas, is then pumped into the furnace. This combines with the oxygen, leaving an impure nickel.

In North America, the nickel is usually refined by electrolysis (similar to the process used for copper oxide), elsewhere the Mond process is generally used.

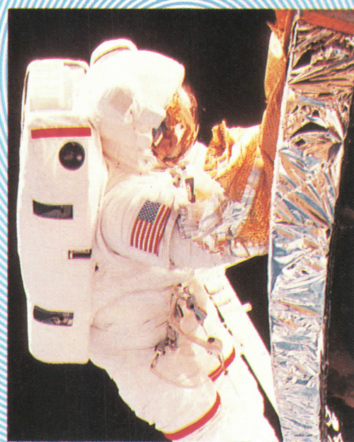
The Mond process consists of a two-stage operation. First, the nickel is heated with producer gas, but this time to only 50°C, which is a much lower temperature than before. This produces a compound called nickel carbonyl, which consists of nickel, carbon and oxygen.

The nickel carbonyl is then heated to about 180°C. At that temperature it gives off carbon monoxide, leaving little pellets of pure nickel.

A lot of tin is found as a pure metal but the main ore is cassiterite (tin oxide). This is found inside rocks, but some of the most important deposits occur in beds of sand and gravel. The ore is converted into tin by heating it in a furnace with anthracite – a hard coal containing a very high percentage of carbon.

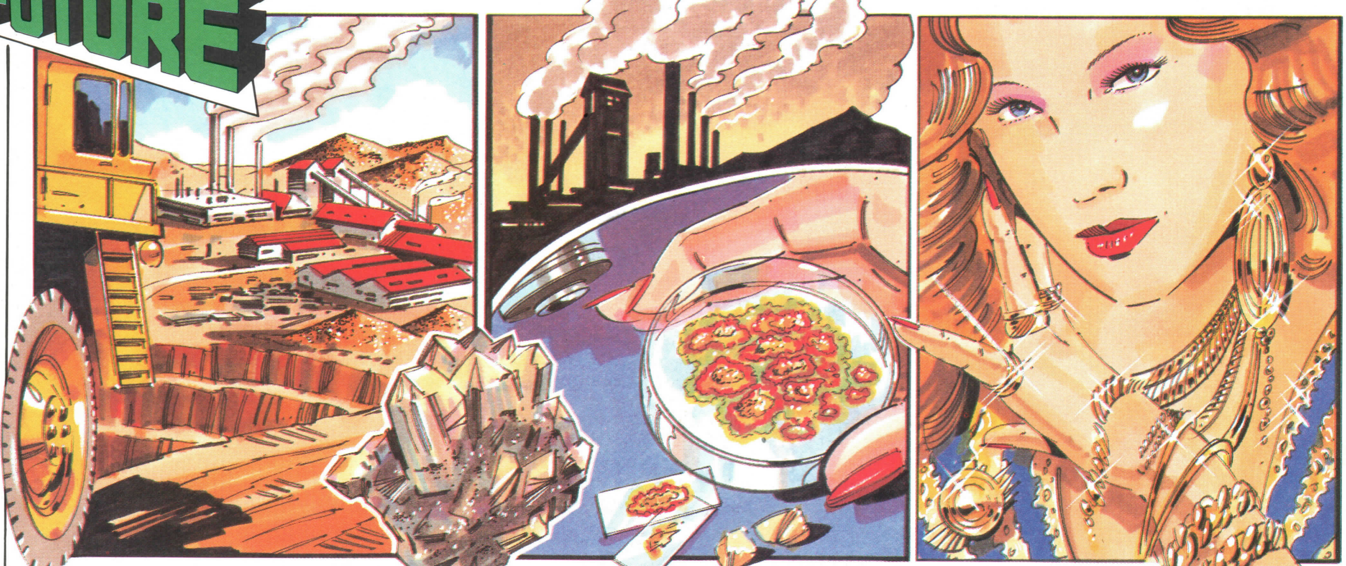
A UNIQUE METAL

Gold is very malleable, which means that it can easily be worked into all sorts of shapes. It can even be beaten out so thin that it becomes transparent. This cannot be done with any other metal. Sheets of this transparent gold are built into the windscreen of Concorde and into the visors of astronauts. A small electric current is passed through the gold, which heats up gently and so prevents the glass misting up.


NASA/Science Photo Library

INTO THE FUTURE

GOLD BUGS


Joe Lawrence

▲ *With conventional processing, a staggering 90 per cent of gold is still left in the ore. The gold is trapped in pyrites (iron sulphides).*

▲ *Because methods of extracting this trapped gold cause severe pollution, scientists are developing a unique group of microbes capable of digesting the pyrites.*

▲ *In doing so, the microbes will expose almost all the gold previously trapped in the sulphide. The gold can then be extracted with cyanide in the usual way.*

INTO THE UNKNOWN

- JUNGLE LORE
- THE DANGERS WITHIN
- INTO THE CANOPY

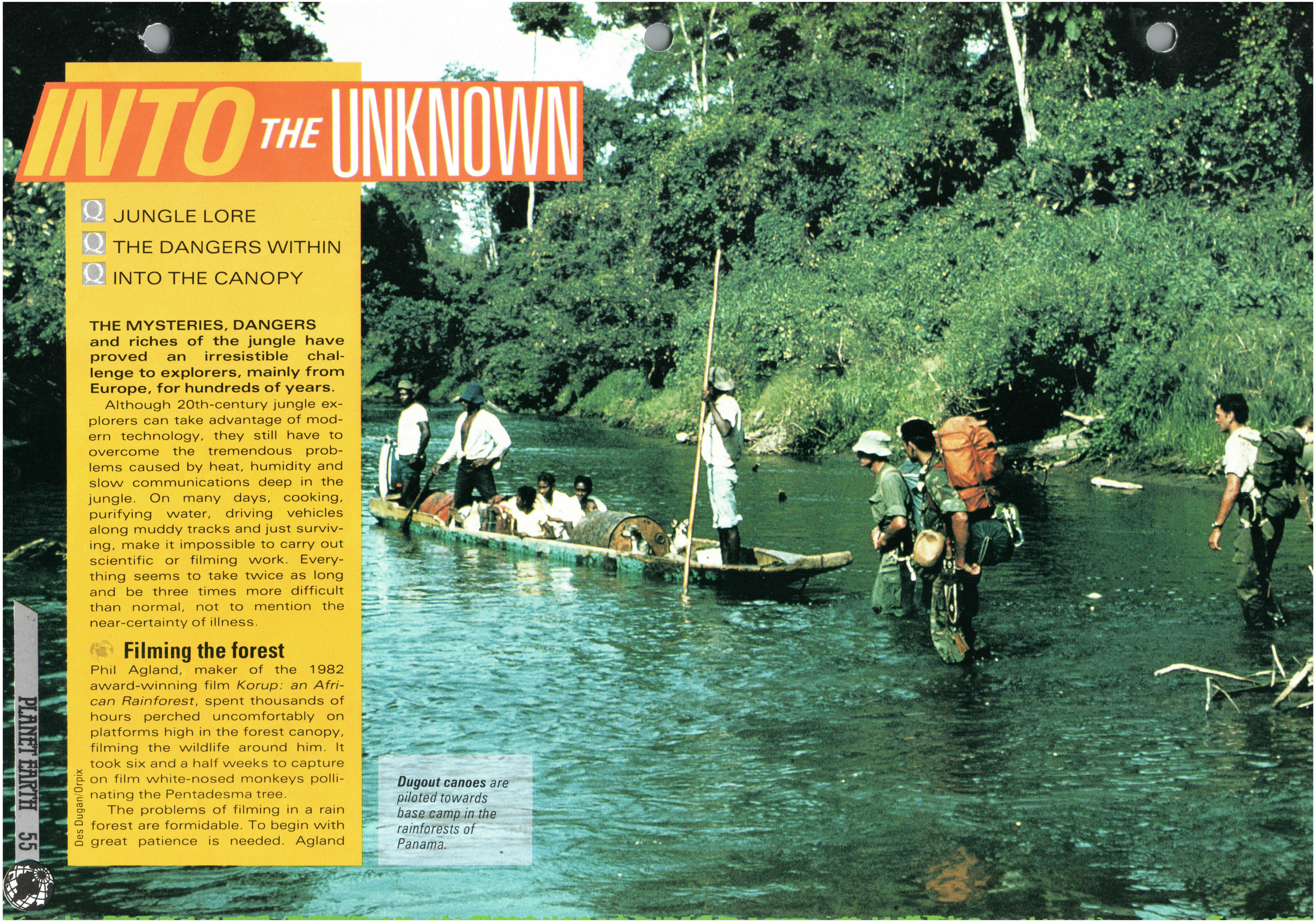
THE MYSTERIES, DANGERS and riches of the jungle have proved an irresistible challenge to explorers, mainly from Europe, for hundreds of years.

Although 20th-century jungle explorers can take advantage of modern technology, they still have to overcome the tremendous problems caused by heat, humidity and slow communications deep in the jungle. On many days, cooking, purifying water, driving vehicles along muddy tracks and just surviving, make it impossible to carry out scientific or filming work. Everything seems to take twice as long and be three times more difficult than normal, not to mention the near-certainty of illness.

Filming the forest

Phil Agland, maker of the 1982 award-winning film *Korup: an African Rainforest*, spent thousands of hours perched uncomfortably on platforms high in the forest canopy, filming the wildlife around him. It took six and a half weeks to capture on film white-nosed monkeys pollinating the Pentadesma tree.

The problems of filming in a rain forest are formidable. To begin with great patience is needed. Agland



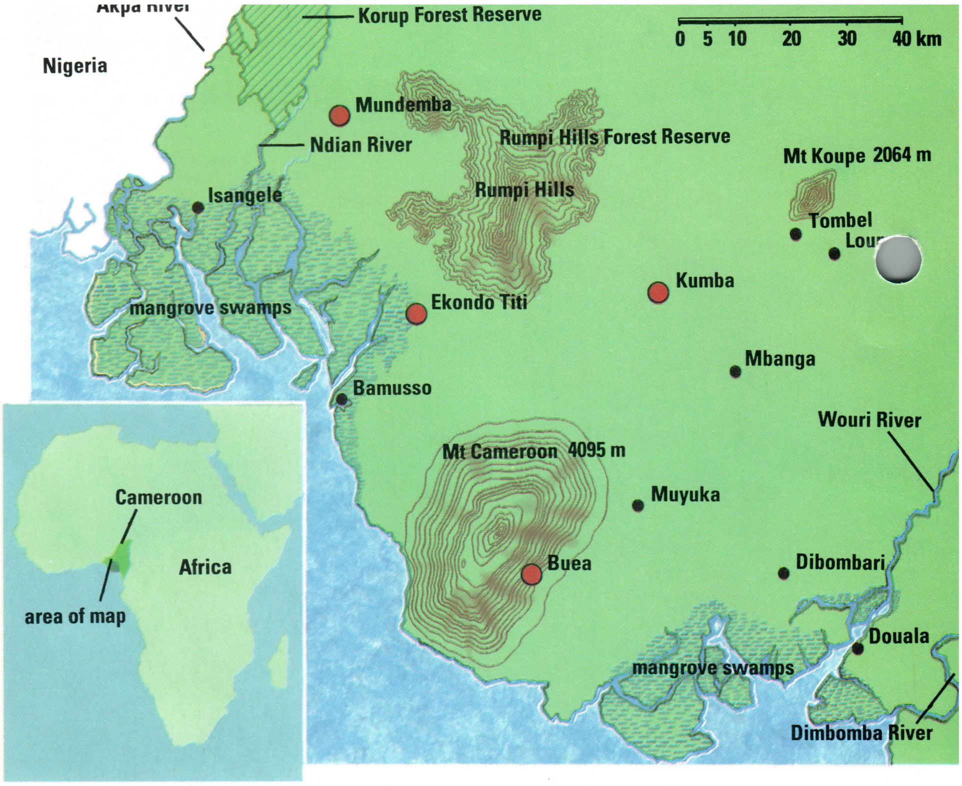
Des Dugan/Orpix

***Dugout canoes** are piloted towards base camp in the rainforests of Panama.*

found fungus growing in his camera and the humidity ruined his unused film. In the end, however, the programmes he made were superb and became the centre of a campaign to save the rain forests.

In the jungle, film crews are often forced to eat unusual foods if their own supplies run out. On a wild boar hunt through a rain forest with the Maku people, the *Disappearing World* team from Granada Television, Manchester, England, had to eat fried flying ants for three days – apparently they tasted like bacon fried in butter. More familiar delicacies, such as rice, corn and various fruits may well be available, but a local guide is essential to tell you which foods are safe to eat.

Today's explorers know that the



Joe Lawrence

The area of an expedition *by the UK based Operation Raleigh team to the Cameroon, close to the Nigerian border in 1989. The team had various objectives, including zoological surveys.*

Christopher Sainsbury/Orpix

J Weddell/Orpix

A moth survey *in Cameroon for the Worldwide Fund for Nature discovered about 1,000 species, 150 of which were new.*

A camera crew *from London, England, working in Belize, Central America, on a film about the diverse life on a fig tree.*

R Fitzgerald/Orpix

The Rio Claro *suspension bridge, on the Osa Peninsula near Drake Bay in Costa Rica, is 30 metres in length.*

Bridge building *in Costa Rica in 1985 – part of a programme to help villagers across the River Claro in the wet season.*

interior of the rain forest is not an impenetrable tangle of greenery with dangerous animals lurking behind every tree. But dangers still exist. Slippery tracks, fallen logs and shallow tree roots that snake across the jungle floor are all potential hazards.

Even leaning against a tree can be hazardous – animals may be disturbed or the tree itself may present hidden dangers. The sandbox tree, for example, has nasty spikes growing out of its trunk, sap that can blind if it gets into the eyes and fruit that explodes and sends poisonous seeds flying up to 20 metres away.

Most larger animals, such as

Partridge Films Ltd

Christopher Sainsbury/Orpix

***Solea base camp** in Seram, Indonesia, was the centre of operations for an expedition that carried out a full rain forest survey of wildlife and plants in 1980.*

snakes, have to be treated with respect. Needless to say all modern expeditions carry snake-bite serum. Ticks have to be carefully removed at the end of each day, as do leeches. A lighted match or pinch of salt is usually enough to make a leech release its hold, but the wounds need to be treated, as a matter of course, with antiseptics and antibiotics. Wounds heal slowly in the hot, humid jungle climate and can easily get infected.

Many insects, such as mosquitos, carry diseases. But today's explorers can be immunized against diseases such as yellow fever and can take tablets to protect themselves against malaria. (Malaria tablets contain quinine, which was originally obtained from the bark of a rain forest tree.)

Slippery climb

Less dangerous insects, such as ants, can be kept out of sleeping bags by putting petroleum jelly on any ropes or strings they might climb in the night. An expedition to film the Waorani people of Amazonian Ecuador was plagued by small stingless 'sweatbees' that could only be shaken off for a few minutes by a dip in the river.

Tents are usually too hot and stuffy for jungles and it is inadvisable to sleep on the ground. The best solution seems to be a hammock with a mosquito net to give

***The forest canopy** offers great rewards but the dangers, as with this wildlife observation hide, are real. An aerial walkway (below) under construction in the jungles of Costa Rica.*

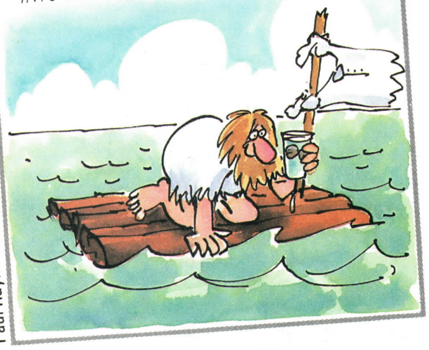
Christopher Sainsbury/Orpix

C Rainer/Orpix

Just amazing!

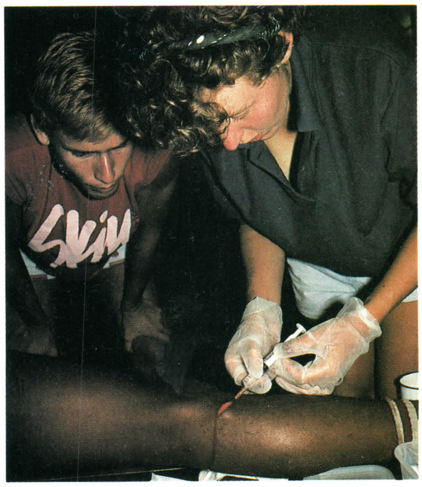
WATER, WATER ...

THE AMAZON IS THE WORLD'S BIGGEST RIVER. IT POURS INTO THE ATLANTIC WITH SUCH FORCE THAT IT IS POSSIBLE TO SCOOP UP A CUP OF FRESH RIVER WATER 160 KM INTO THE SEA.



Paul Raymonde

***Primary health care** programmes, such as this one in Guyana in 1988, are one of the many purposes of modern expeditions to the tropical rain forests of the world.*



Annette Price/Orpix

protection from moths, flying beetles and bats as well as mosquitos. A waterproof plastic sheet acts as a 'roof' - but if this has any folds where water can collect, you can be drenched in the middle of the night by an unexpected shower.

One of the most rewarding pursuits in the jungle is to climb to the canopy. It is dangerous, but such danger is an everyday occurrence for natives who climb using only a simple harness of vines to obtain honey from high in the trees.

To climb into the canopy, Donald Perry, a biologist exploring the jungle canopy in Costa Rica, used mountaineering gear. This allowed him to slowly inch his way up into the thick, jungle roof. A crossbow fired ropes over high branches.

Hutchison Library

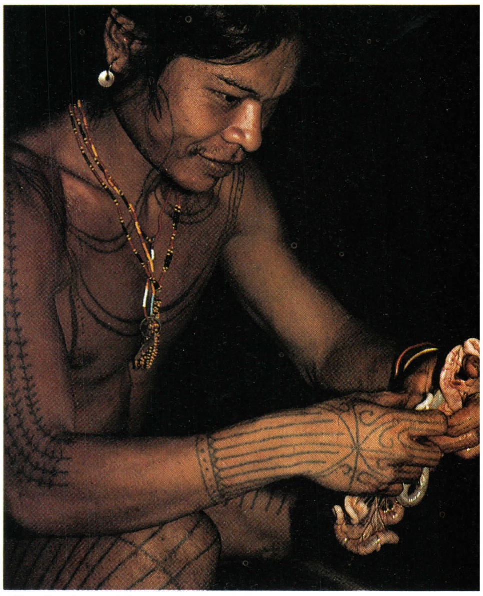
The Mehinacu tribeswomen of the Amazon have their legs bound to bloat their calves as part of their initiation into the tribe.

The annual feast of the Tanna people of Vanuatu begins with the ritual clubbing to death of the prized tribal pigs.

Kal /Susan Griggs Agency

Dressed up for a special occasion, a Yanomami Indian girl from Brazil wears the tribal equivalent of lipstick and mascara. The face painting represents animal spirits.

Victor Englebert/Survival International



J Mackinnon/Bruce Coleman Ltd

Animal intestines are the key to reading the future for a Siberut tribesman, native to Western Sumatra, in the East Indies.

L C Marigo/Bruce Coleman Ltd

The Kanela Indians of the Brazilian rain forests traditionally perforate their ears with sharpened sticks (above) and then fill the holes with a large, circular plug of wood for decorative purposes.

L C Marigo/Bruce Coleman Ltd

Marcus Brooke/Colorific!

Tribal warriors of the Bawo Mataluo Indians of Nias, an island in Indonesia, perform a traditional warriors' dance.

Body paints are both decorative and symbolic for the Xingu Indian tribespeople of the Brazilian rain forest. The colourings are ground from plant or animal preparations.

Robert Harding

THE GREENHOUSE EFFECT

- RESPIRATION
- THE WATER CYCLE
- GLOBAL WARMING

RAIN FORESTS COVER around ten per cent of the world's land surface – roughly the area of Europe – but they are rich out of all proportion in wildlife.

They contain three-eighths of all the known species of land plants and one-third of the total weight of land plants and animals. The Amazon alone – the largest single area of jungle – is thought to be home to about half of all the plant and animal species in the entire world.


P E Parker/Hutchison Library


Harald Sund/Image Bank

If the jungles continue to be cut down at the same alarming rate, tropical rains (inset left) will cease and much of the Earth's surface could end up as desert. The rain forests' water cycle controls the global climate and helps maintain farmland.

More than 30 billion tonnes of plant material grow in jungles annually – at 90 tonnes per hectare per year, this is twice as much as in a temperate forest in Europe or North America.

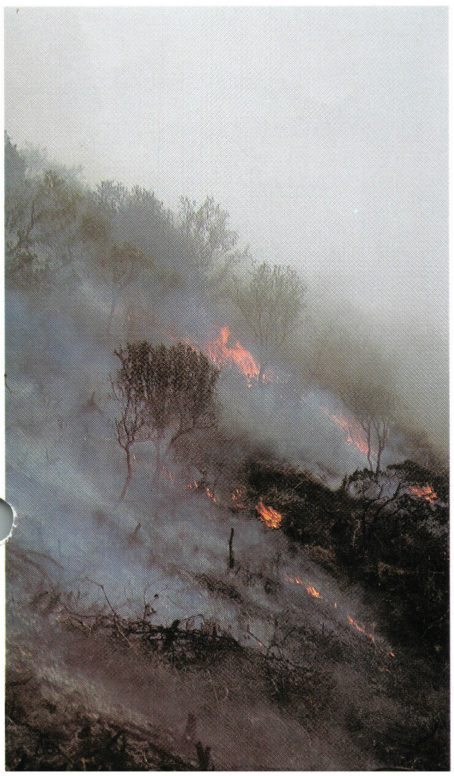
Essential cycles

Tropical rain forests are not only the richest places on Earth for plants and animals, they also affect global temperature, rainfall and weather patterns. Cutting them down could have – and perhaps is having – disastrous effects all over the world.

Plants take in carbon dioxide from the air, water and nutrients from the soil and use the Sun's energy to build living tissue by the process of photosynthesis. As a by-product of this process, oxygen is given off. All living things – both plants and animals – breathe in this oxygen.

Animals eat plants and so take in the nutrients produced in the plant by photosynthesis. Using the oxygen they breathe in, animals convert some of these nutrients to produce energy. As a by-product, carbon dioxide and water vapour are produced – both of which the animals breathe out. The remaining nutrients are used and excreted. The waste goes directly back into the soil and, when plants and animals die, they rot and thus provide nutrients for re-use.

Water and nutrients from the rain-soaked soil are sucked up through the roots of forest trees. The water, carrying the nutrients, passes up the trunk and stem into the leaves, and evaporates as water vapour. The water vapour rises into the air, condenses to form clouds, and falls again as rain.


Vaughan Fleming/Science Photo Library

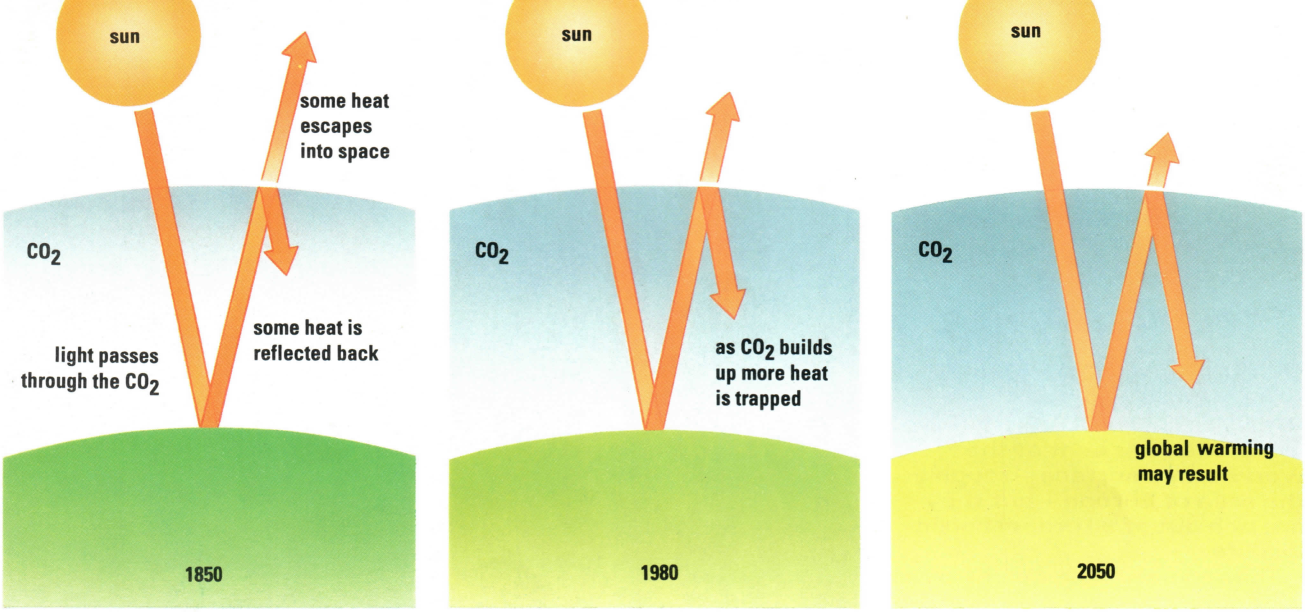
The burning of rain forests to clear the ground for livestock pumps even more carbon dioxide into the atmosphere.

Changing the weather

Normally, forest trees hold the soil between their roots, trapping the water and preventing erosion, which occurs when the jungle is felled.

In the Amazon the felling and

The Heat Trap



Joe Lawrence

Sunlight passes through *the atmosphere easily, but heat is reflected back to Earth by the carbon dioxide (CO_2). Atmospheric carbon dioxide has been increasing steadily since the industrial revolution in the mid–1800s. The burning of the rain forests and fossil fuels – such as petrol – are inviting a global crisis in the 21st century.*

Flooding in Asia *was caused by eroded soil from deforested areas washing into the rivers until they burst their banks.*

J H C Wilson/Robert Harding Picture Library

burning of the rain forest has altered local climate. Once the forest disappears it becomes windier and drier. When rain does fall, the forest trees are no longer there to stabilize the shallow soil and soak up the moisture.

Instead, water runs straight into the rivers and causes floods. It carries the loose soil with it, which clogs the local waterways, irrigation channels and hydroelectric dams. The land is left bare, infertile and barren.

A thin layer of gases, including carbon dioxide and ozone, surrounds the Earth and makes 'life' possible. Infrared (heat) rays from the Sun pass through the atmosphere and are absorbed by the land and sea. Some of this heat is then radiated back into the atmosphere. But this radiation is of a longer wavelength and much of it is prevented from escaping by carbon dioxide and certain other gases. These gases thus act like the glass of a greenhouse, helping to keep the Earth warm.

For millions of years, this process has maintained the temperature of the planet at a roughly steady state. The problem now is that the amount of carbon dioxide is increasing as human beings burn more wood, coal, petrol and other fuels. The global warming that results is becoming known as the 'Greenhouse Effect'.

The Earth's equator receives the most energy from the Sun. the jungles on the equator are dark green and absorb heat easily – and have been doing so for millions of years. But open, agricultural land such as wheat or corn fields, or the wasteland produced when rain forest is cut down, reflects the heat back into the atmosphere. This 'mirror effect' could contribute to the overall global warming with grave consequences.

New bread-basket

If the tropical forests become vast grain-growing areas, this would act as a 'mirror' and reflect the Sun's warmth – which could then be trapped by the thicker blanket of carbon dioxide.

As temperatures rise and weather patterns alter, the world's current grain-growing areas such as in the USA and the former USSR could dry out and become deserts. At the same time, colder regions farther North would warm up enough to grow wheat and so – in theory at least – they could become the new bread-basket for the world.

Just amazing!

UNSPORTING

AN AREA OF JUNGLE THE SIZE OF A SOCCER PITCH IS CLEARED EVERY SIX SECONDS IN THE LUSH REGIONS OF AMAZONIA.

Paul Raymonde

- GENETIC CODES
- MAKING PROTEINS
- MUTATIONS

MOLECULE OF LIFE

EVERY INDIVIDUAL IS UNIQUE. And what makes every individual unique is a series of long molecules known as DNA (deoxyribonucleic acid).

Threads of DNA are found in the nucleus of every living cell and they are called chromosomes. In a human being the length of a single thread can be almost 1 metre when it is unravelled. Threads of DNA act like computer discs, storing the huge amount of information needed to make a human being, a dog, a pig, a sweet pea plant or whatever, depending on which organism they are taken from.

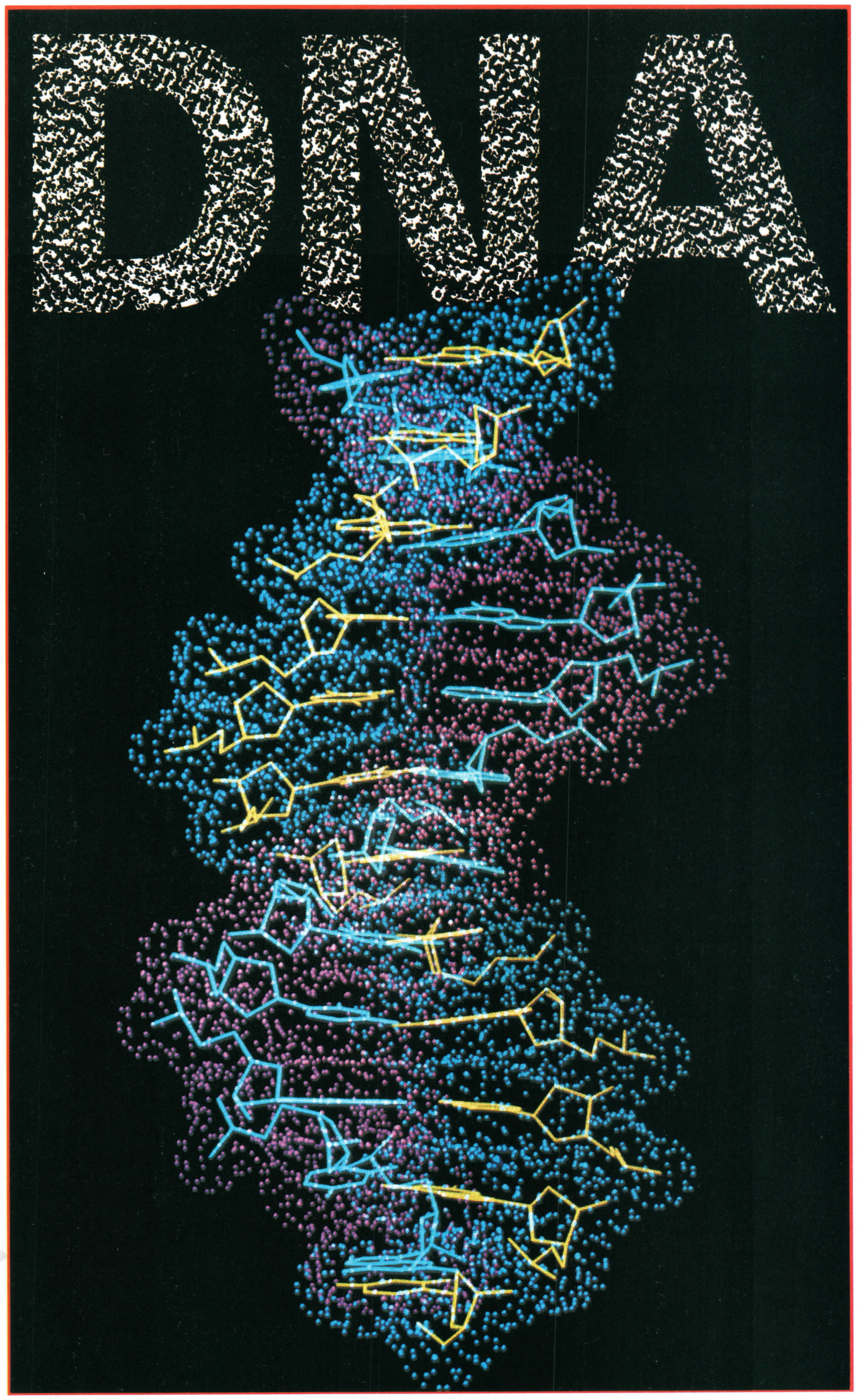
Replication

What makes DNA the very stuff of life are its ability to replicate and to be decoded into the proteins that help to make up a living being.

In a living, growing organism, new cells have to be produced. This is done by old cells dividing in two. Shortly before this happens, the two strands of the DNA double helix (a helix looks like a screw-shaped coil) uncoil and chemically replicate. The DNA molecules then coil up upon themselves and the chromosomes begin to look like the familiar 'X' shape. The two sets of chromosomes move to opposite sides of the cell, which then divides, with each new cell carrying a complete set of chromosomes contained within the nucleus.

A human chromosome carries around 80,000 genes. These carry the coding for the thousands of proteins that make up the human body. Simple organisms have fewer genes.

In many organisms, chromosomes come in pairs. The fruit fly has four pairs, the chicken has 39 pairs and Man has just 23 pairs – 46 chromosomes in all. These 46 chromosomes appear in the nucleus of every cell in the body – except the sex cells. Sperm cells and egg cells have only 23 chromosomes each – so when the sperm penetrates the egg during reproduction, the resulting cell has the full complement of 46 chromosomes. The combination, though, is new and defines a complete, new, unique individual – their sex, their hair colour, the colour of their eyes, etc. It could even mean that they are an albino, with white hair and pink eyes. This is caused by a single gene mutation that is quite common, being found in one in 50 of us.



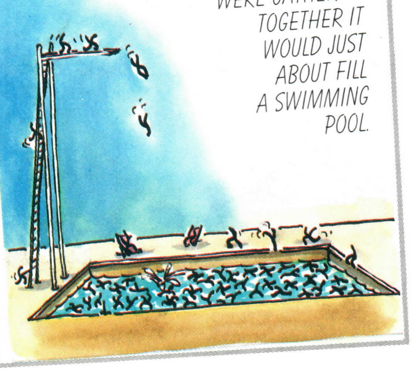
***A strand** of DNA coiled in a double helix, as revealed by false-colour computer graphics.*

Oxford Molecular Biophysics Laboratory/SPL

Just amazing!

THE GENE POOL

IF ALL THE DNA IN ALL THE CELLS OF EVERYONE IN THE ENTIRE WORLD – ALL FIVE BILLION OF US – WERE GATHERED TOGETHER IT WOULD JUST ABOUT FILL A SWIMMING POOL.

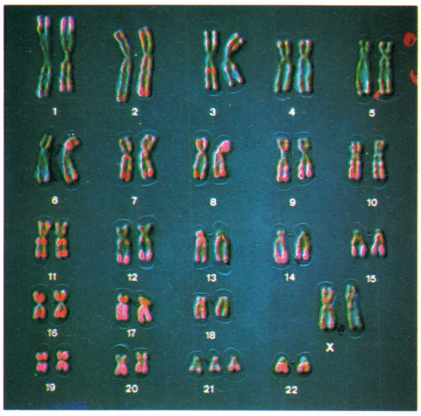


Paul Raymonde

BODY TALK

Cell The smallest unit of life that can exist on its own, the building block from which all plants and animals are constructed.
Chromosome A thread-like structure, a number of which are found in the nucleus at the centre of every cell.
DNA (deoxyribonucleic acid) The chemical that makes up a chromosome.
Gene A tiny part of a chromosome. Genes control inherited characteristics.
Sperm and egg The male and female sex cells, which join to form a new individual.

Richard Hutchings/SPL



CNRI/SPL

***An extra chromosome** in pair 21 of these matched pairs of human chromosomes is a sign of Down's Syndrome. Sufferers (such as the boy above) are born with low IQs and die young. However, they respond well to teaching and have loving natures.*

However it only rarely has any effect. Albinos have no melanin – the colouring agent in skin, hair and eyes.

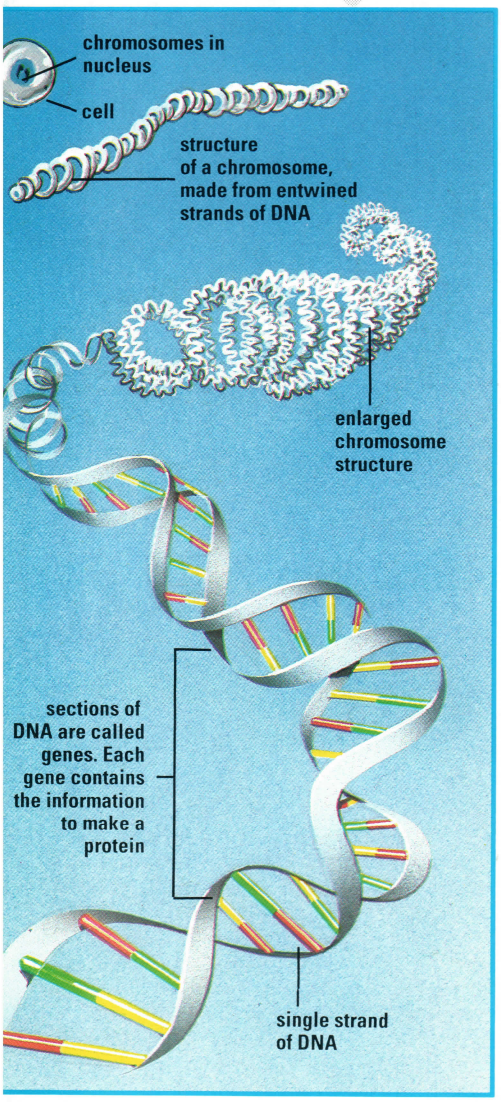
At any stage of DNA replication a mistake may be made. Sometimes a gene is radically altered, either by errors in replication or by outside agents like prolonged exposure to ultraviolet light, X-rays or radioactivity. These changes are called mutations.

If a mutation occurs that affects a sex cell, it may be passed on from generation to generation. If the mutation is helpful, the individual will flourish and its offspring will spread – this is the mechanism of evolution. But if the mutation is unhelpful, a genetic disease may spread down the generations.

One example is the blood disorder sickle-cell anaemia, which mostly effects Mediterranean and African people. The red blood cells are formed in the shape of a sickle rather than a disc. This means they break up more easily and get stuck in smaller blood vessels. The gene that causes sickle-cell anaemia is passed from parent to child and up to 100,000 people die from the disease each year.

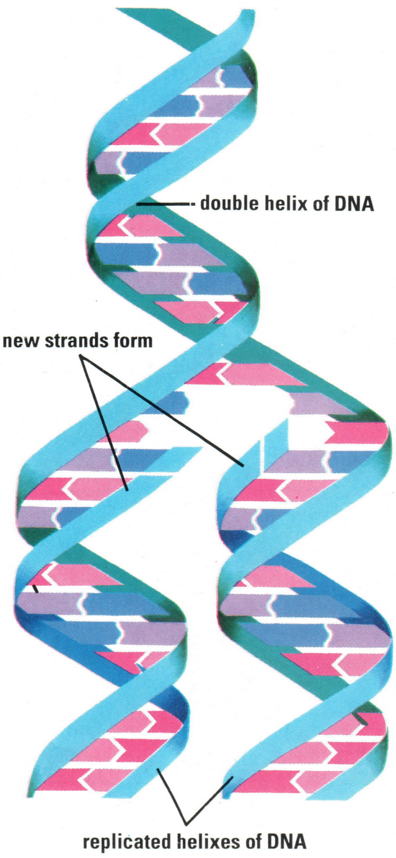
There are other forms of genetic disease too. Down's Syndrome is caused by the existence of a whole extra chromosome. This gives those affected their distinctive features and makes them mentally retarded. Their IQs range from 30 to over 70 (the average for normal people is 100).

***DNA is a strand of protein** found within chromosomes, the long thread-like bodies inside the nucleus of every living cell.*



Jane Burton/Bruce Coleman Ltd

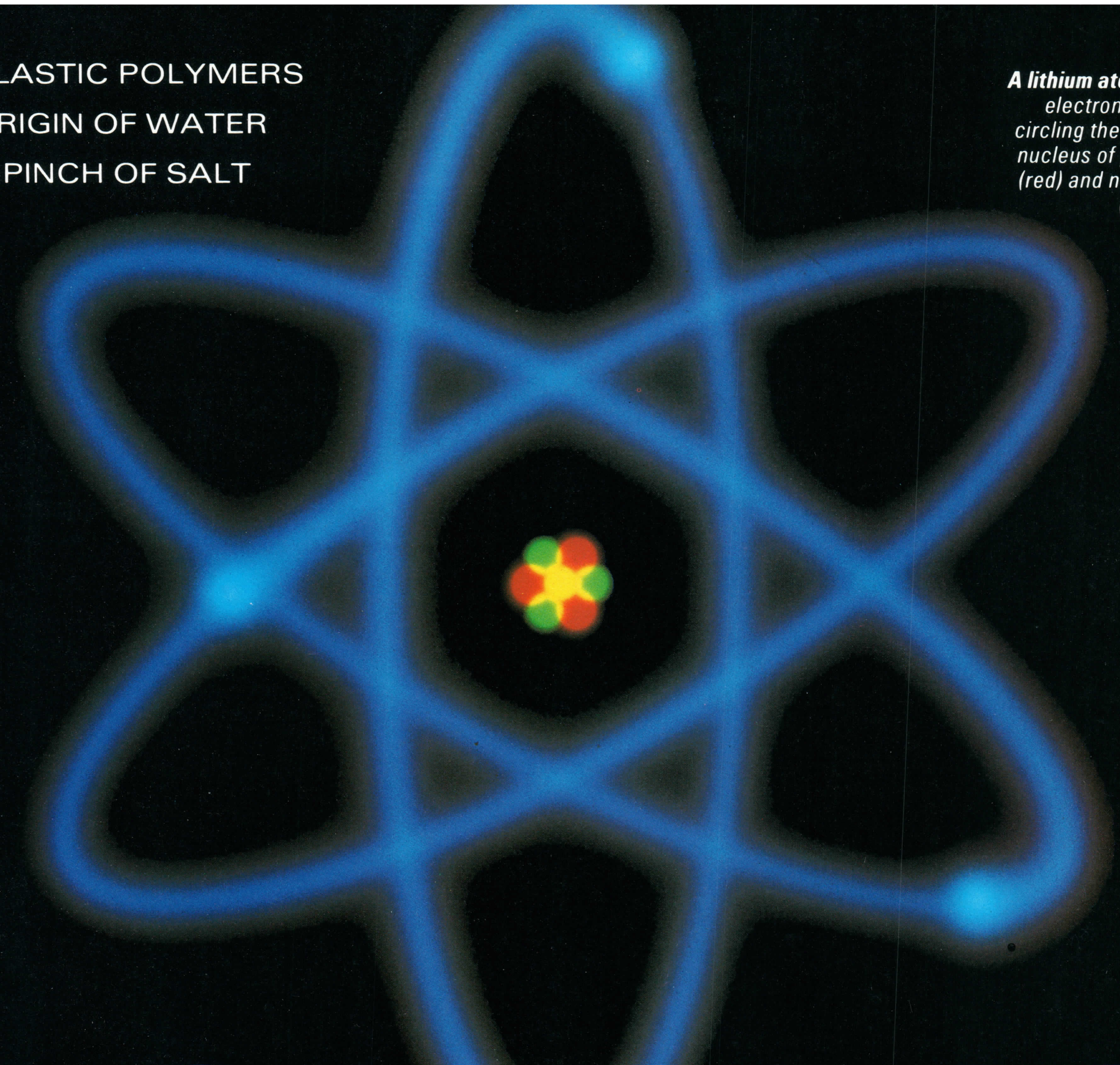
***The Indian Muntjac** deer has the least chromosomes of any mammal. The female has six, the male seven.*



Caroline Brodie

***When DNA uncoils,** it is chemically replicated. Matching proteins copy the sequence of the strand.*

- PLASTIC POLYMERS
- ORIGIN OF WATER
- A PINCH OF SALT



***A lithium atom** with electrons (blue) circling the central nucleus of protons (red) and neutrons (green).*

David Parker/SPL

BONDING

EVERYTHING ON EARTH, including ourselves, is made up of tiny atoms – building blocks that fit together in many different ways. These atoms are each less than one ten millionth of a millimetre in size.

Groups of atoms joined together are called molecules. Oxygen atoms, for instance, can combine with each other to form oxygen molecules, or with hydrogen atoms to form water molecules. Molecules consisting of atoms of two or more different elements (such as oxygen, hydrogen or carbon) are called compounds.

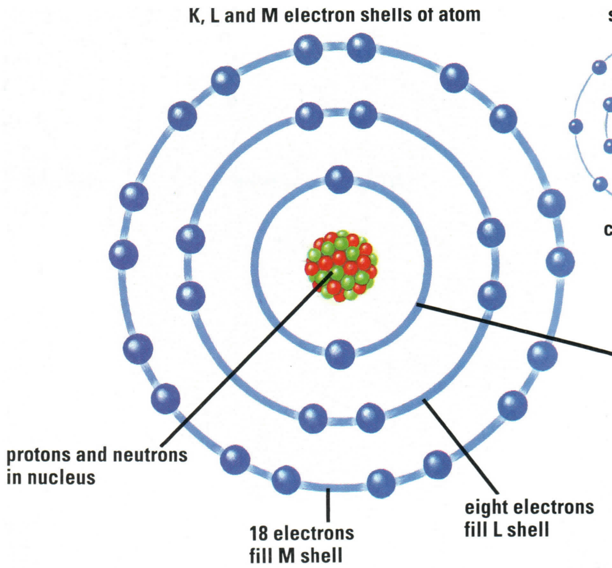
Compounds can be quite simple substances with only a few atoms per molecule, as in water or salt. But some compounds, especially those found in plastics and in plants and living creatures, can have large and very complicated molecules as in substances known as polymers. Natural polymers include cellulose, resins and rubber; synthetic polymers include plastics such as nylon, polyurethane and polythene.

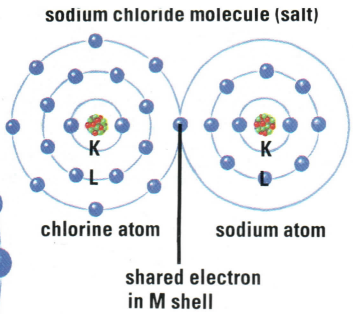
Inside every atom is a central core – the nucleus – which is a tiny clump of particles called protons and neutrons. The number of protons and neutrons in the nucleus varies from one element to another. A carbon atom, for instance, has six protons and six neutrons, while an oxygen atom has eight protons and eight neutrons within the nucleus.

The nucleus of an atom is surrounded by a cloud of even smaller particles called electrons, and there is one electron for every proton. Each proton has a positive electric charge, and each electron has a negative electric charge. Because there are equal numbers of protons and electrons, their electrical

__Rock salt__ is cut out of the underground salt beds in large blocks. These are crushed and sorted into different grades. By the use of anticaking agents salt can now be stored outdoors and uncovered without hardening into a solid mass again.

ICI Chemicals & Polymers





The electron shells of an atom – known as K, L, M, N, O, P, and Q shells – can only hold electrons if the adjacent inner shell is 'full up'. Each shell holds a different number of electrons.

Caroline Brodie

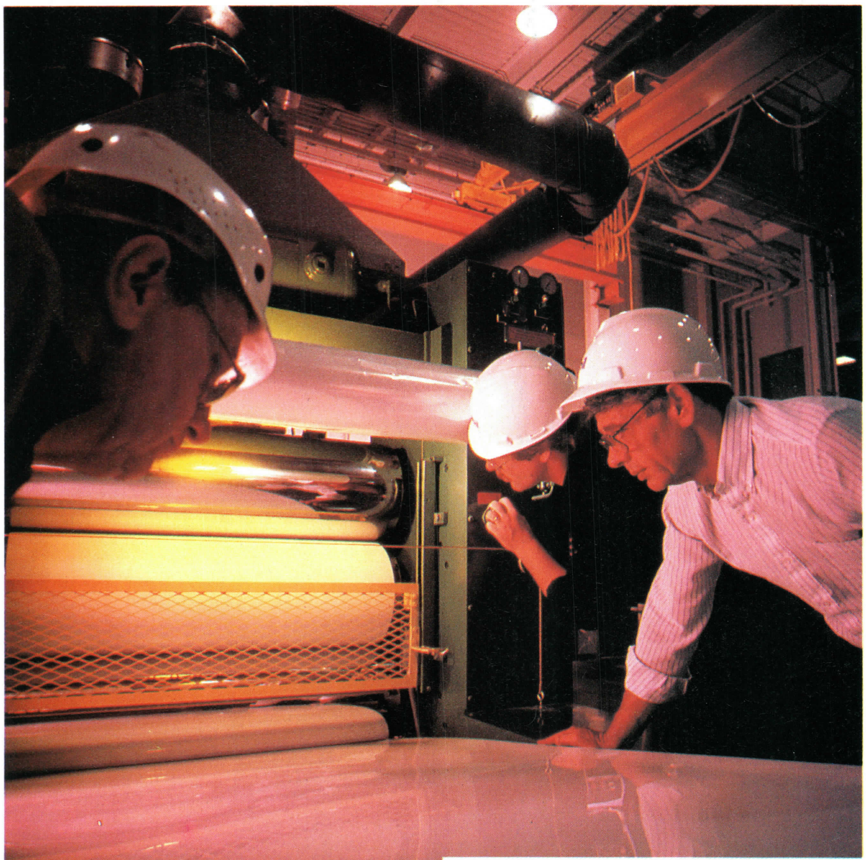
charges balance and so, overall, the atom has no electric charge.

The electrons are arranged in a series of concentric orbits or 'shells'. The way in which an atom can combine with other atoms to form molecules depends on the number of electrons in its outermost shell.

The electron shells are known as the K, L, M, N, O, P and Q shells, proceeding outwards from the centre of the atom, and there is a maximum number of electrons that can be in any one shell. The K shell, for example, can hold two electrons, and the L shell (the next one out) up to eight.

Sharing electrons

The process of atoms forming molecules by sharing electrons is known as covalent bonding. Because an oxygen atom has eight protons, it also has eight electrons. Two of these fill up its K shell, and the rest go into the L shell. But the L shell can hold up to eight, so it has room for two more. It will try to fill the vacant spaces in the shell and one way to do this is by sharing electrons with other atoms — for instance with hydrogen atoms.



ZEFA

***Plastic film** is made by calendering – the plastic is melted before being squeezed and stretched on rollers.*

The hydrogen atom is the smallest and simplest atom of all, having a single proton for a nucleus and a single electron orbiting it in the K shell. As there is only one electron in the K shell, the atom has room for one more. If two atoms of hydrogen meet up with an oxygen atom, each hydrogen atom will share its electron with the oxygen atom. The result is a molecule of water.

Another way in which atoms can unite to form molecules is by ionic bonding. (An ion is an atom that has an electrical charge). This is what happens when, for instance, sodium combines with chlorine to form common salt (sodium chloride) — the kind you put on your food.

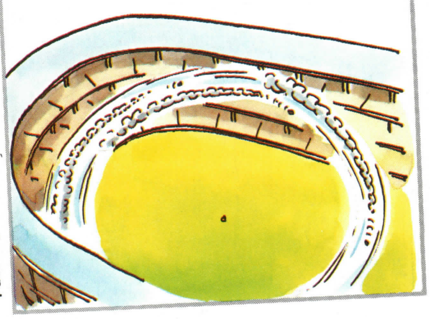
A sodium atom has 11 electrons, two in its K shell, eight in its L shell and one in its M shell. A chlorine atom has 17 electrons, two in the K shell, eight in the L shell and seven in the M shell. When sodium and chlorine combine to make salt, each sodium atom gives its single outer electron to a chlorine atom.

This leaves the sodium atom with one electron fewer than its number of protons, so it then has an overall positive electrical charge. The chlorine atom, however, now has one more electron than its number of protons, so it has an overall negative charge. The two atoms are thus attracted to each other.

Just amazing!

NUCLEUS ONE, ELECTRONS NIL

IF THE NUCLEUS OF AN ATOM WAS A PEA IN THE MIDDLE OF A FOOTBALL PITCH, SOME OF ITS ELECTRONS WOULD BE ORBITING AROUND THE EDGE OF THE STADIUM – SO GREAT IS THE DISTANCE BETWEEN THEM.



Paul Raymonde

A CHAIN OF ATOMS

Chemical Design Ltd Oxford/SPL

Small groups of atoms that are repeated over and over again like links in a chain are called polymer molecules. A single polythene molecule, for instance can be a long chain of over 25,000 carbon atoms, each with two hydrogen atoms bonded to it. This makes the material easy to work.

ROCKS OF AGES

- LAYERS OF ROCK
- THE FOSSIL TRAIL
- RADIOACTIVE CLOCK

PLANET EARTH IS A RESTLESS beast. Nothing could seem more solid and durable than the mountains and the land. Yet, viewed over millions of years, mountains are born and die, oceans advance and recede, while whole continents drift, rotate and collide.

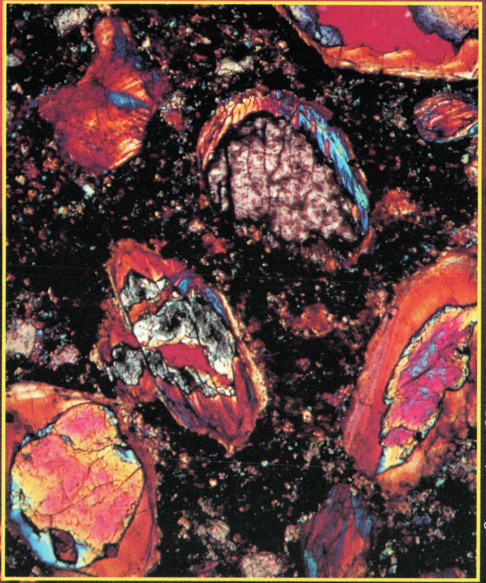
You can often see a small cross-section of the Earth's crust exposed. This happens in cliffs, in the rocky sides of a quarry, or a valley, or in an outcrop of rock that is bare of soil. Often the rock has a clearly visible layered structure. Each of these layers is called a stratum (more than one are 'strata'). The strata are often tilted or folded but each was originally level.

Sedimentary rocks

A stratum begins as a layer of sediment – silt, sand or both – under a body of water. The water might be an ocean, a river estuary or a swamp. In time, further layers of sediment build up. The colour and texture of these layers varies according to the composition of the sediment and the speed at which it is deposited. Eventually, a stratum is compressed by the huge weight of the rocks above. The grains of sediment are cemented together by minerals deposited from water, turning the sediment into rock.

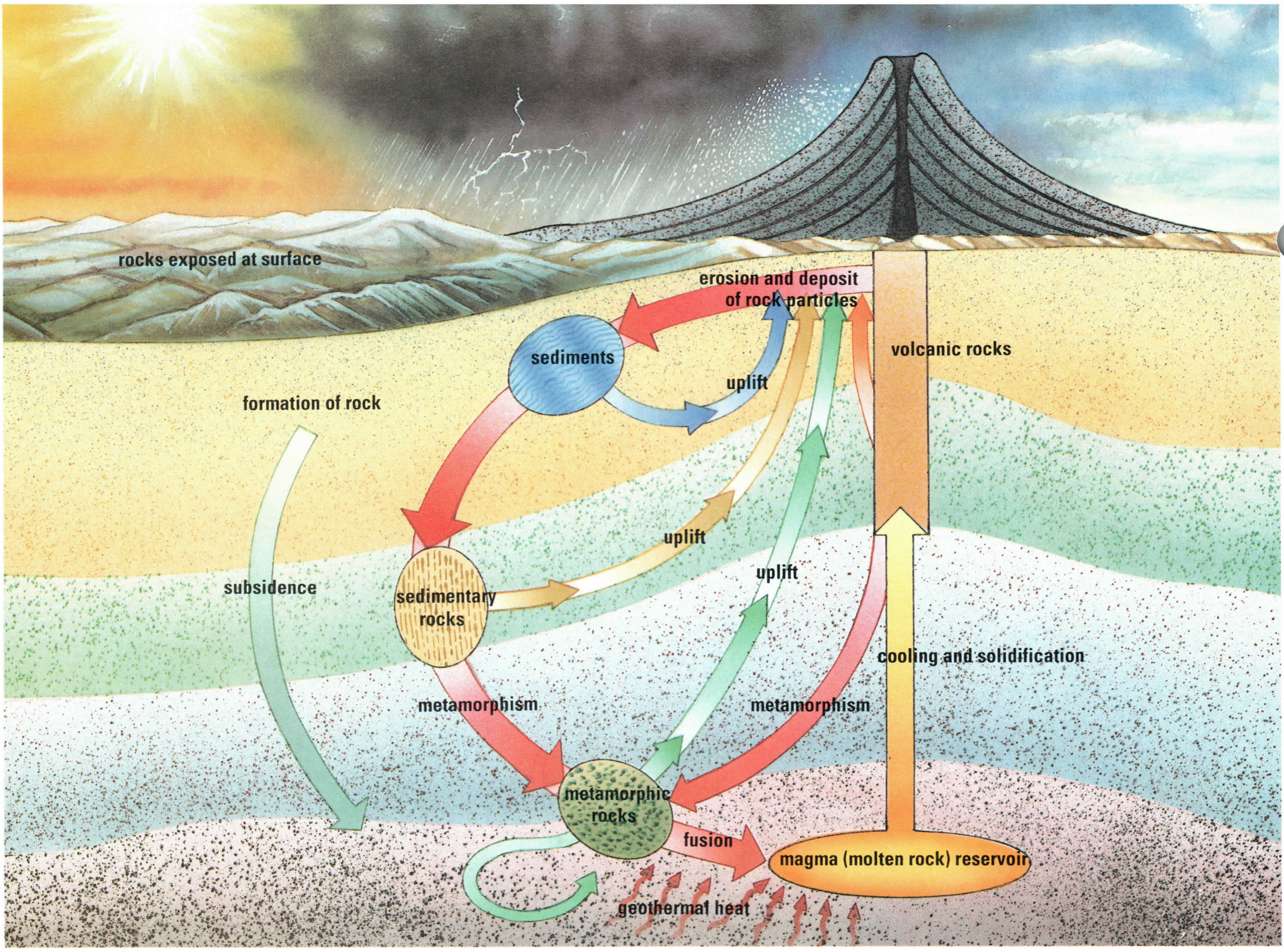
Later, over immense periods of time, the strata may be affected by upheavals in the Earth's crust. They may be folded and tilted and raised above the sea, where they will be eroded by wind, weather and flowing water.

The creation of rock, exploding from a volcano and flowing in an unstoppable 1,000°C river.



Crystals of a volcanic rock called augite, photographed through an electron microscope.

Soames Summerhays/SPL; Jan Hinsch/SPL



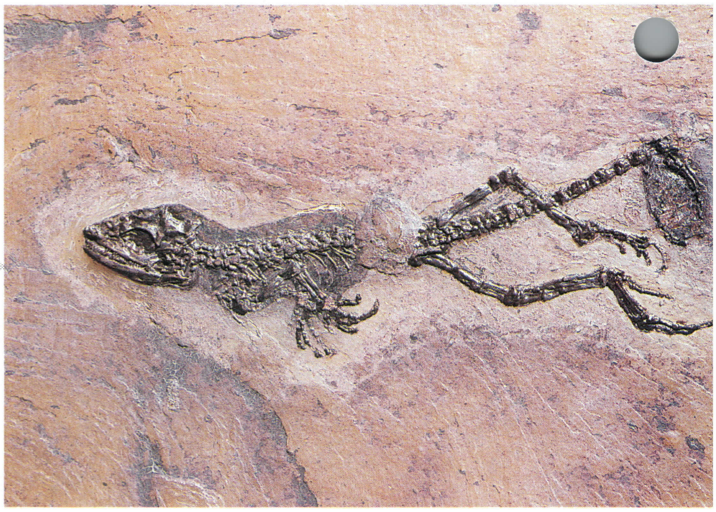
John Houghton

Although nearly all sedimentary rocks look as if they are made like a layer cake, most of the Earth's strata do not actually lie in neat, regular layers. Rock strata may plunge beneath the surface in some places, then reappear far away. In places like coastal cliffs or river canyons, they may have been worn away completely. But strata in one location can often be identified with those found elsewhere. A clue to identification is given by fossils.

The Earth's rocks *move around in a perpetual cycle, changing from one form to another as time passes.*

Fossils, *such as this ancient reptile, are the remains of animals or plants, preserved in stone over millions of years.*

Ammonites *are shelled animals that lived between 200 and 70 million years ago and are very useful in dating rock strata.*



ZEFA

GSF Picture Library

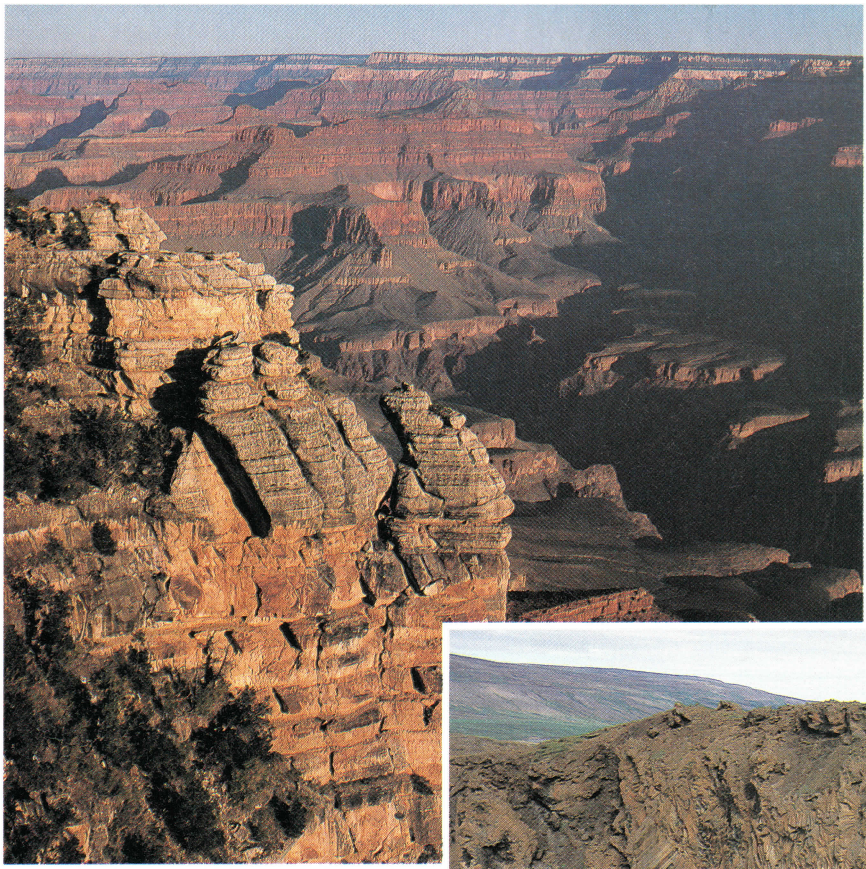
Fossils are remains or traces in the rock of once-living creatures. They may consist of bones or shells that have been turned into rock by chemical processes. Very occasionally, soft tissues may be fossilized. Alternatively, fossils may consist of holes or impressions in the rock, left behind when the creature's remains were dissolved and washed away. They can even be animal footprints or trails.

Dating fossils

Many different creatures have come and gone in the Earth's history, so the fossils in a rock stratum help to date it. In turn, when a new type of fossil is found, it may be dated by identifying the stratum.

The study of strata and their fossils is one of the methods of 'relative dating'. This can reveal the *order* in which events happened and which rocks are older than others. But in itself, it does not provide 'absolute dating' – it does not, in other words, tell geologists how old a rock is in years.

Also, many rocks are not sedimentary – they are not formed from sediment. These are formed when molten rock from the hot depths of the Earth cools and solidifies, either underground or on the surface. Such rocks are known as igneous rocks. They do not form strata and, although it is often



Spectrum Colour Library

***The Grand Canyon** in Arizona, USA, is a 1 km-deep gash in the Earth's crust; it exposes 12 major layers of rock that once lay beneath sea.*

Simon Fraser/SPL

***Volcanic rocks** formed from surface lava sometimes cool into hexagonal columns, as seen on these cliffs.*

possible to relate them to strata that they have covered or otherwise disturbed, there is still the problem of absolute dating.

Fortunately, the solution is provided by radioactivity, which can be used as an extremely accurate 'clock'. Radioactivity is present everywhere; there is a small amount in all rocks, as well as in the air and the sea. Radioactivity is caused by the atoms of certain chemical elements changing into atoms of other elements. When the element changes it sends out radiation.

For example, one type of potassium, called potassium-40, turns into argon-40, a gas. The process is called 'radioactive decay'. A rock containing potassium would initially have contained little or no argon. Some of the potassium would be radioactive potassium-40. With time, as the potassium-40 decayed, the amount of argon would build up. So, measuring how much argon-40 and potassium-40 the rock now contains is a way of estimating the rock's age.

The key to the radioactive 'clock' is something called the half-life. The half-life of any radioactive element is the time that it takes for half of any quantity of it to decay. The half-life of potassium-40, for example, is 1,300 million years. So, if you took any quantity of potassium-40, small or large, 1,300 million years later you would find that only half of it was left. The rest would have decayed into argon.

The oldest rocks

Similarly, it takes 4,500 million years for half of a quantity of uranium-238, another radioactive element, to decay into one type of lead. So, measurements of such radioactive elements can be used for measuring the ages of very old rocks. Some crystals of the mineral zircon, found in Western Australia, are claimed to be the oldest known rocks on Earth, with a measured age of nearly 4,300 million years. The Earth itself is thought to have been created about 4,600 million years ago.

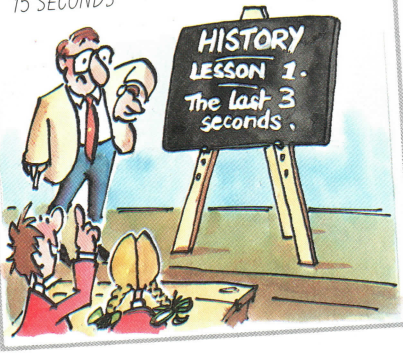
Carbon dating

Radioactivity can also be used to measure comparatively short periods of time — a mere few thousand years. The technique is popularly called carbon dating. The key to this is a radioactive form of

Just amazing!

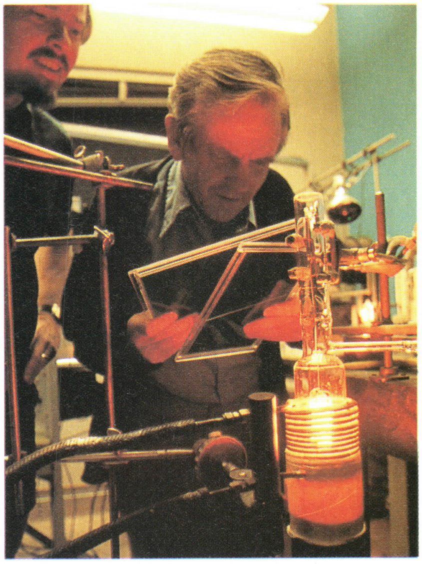
JUST A SEC!

IF THE 15 BILLION YEARS THAT THE UNIVERSE HAS EXISTED WERE REPRESENTED BY ONE YEAR, RECORDED HISTORY WOULD OCCUPY JUST THE LAST 15 SECONDS

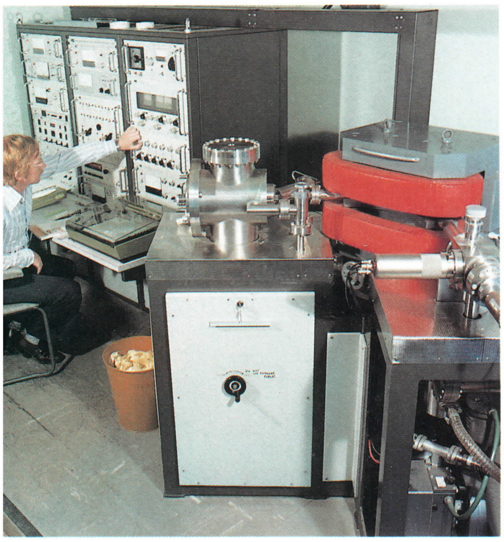


Paul Raymonde

***Radioactive dating** enables geologists to determine the age of volcanic rocks with a great degree of accuracy.*



John Reader/SPL



HMSO/British Geological Survey

***A mass spectrometer** is used to detect and measure radioactivity in rock samples to determine absolute age.*

carbon – one of the most abundant elements on Earth – carbon-14. Carbon-14 is present as a small proportion of the carbon in the air. It is formed from nitrogen by the action of cosmic rays (high energy particles travelling through space) and is always found in the tissues of plants, which absorb carbon dioxide from the atmosphere.

When a plant dies, the carbon-14 in it is no longer renewed from the atmosphere. It simply decreases as it decays into a form of the gas nitrogen.

COUNTING TREE RINGS

The counting of rings to establish the age of a tree is known as dendrochronology. In the early part of the growing season new growth is characterized by large, thin-walled cells that make the wood appear light whereas later growth is characterized by smaller, thick-walled cells that make the wood appear darker. It is the contrast between the dark wood and the light wood of the next year's growth that make the rings. The rings are counted from the centre to the bark. Each ring equals one year.

Spectrum Colour Library

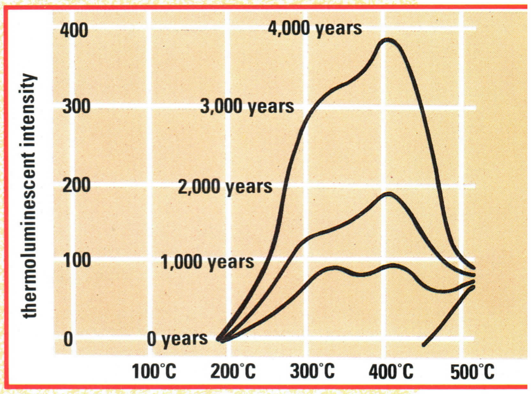
CLUES FROM POTTERY

Side by side with the geologist's task of constructing a history for the rocks of the Earth is the archaeologist's task of contructing a history for hùman beings and their tools and possessions.

One of the commonest clues is pottery. The great durability of pottery means that it is one of the archeologist's main sources of information about the past. The pottery's appearance and style can help pinpoint the culture and time it belongs to. Sometimes, however, the clues are not so obvious – only fragments, for example, may exist – and the archaeologist must turn to more sophisticated dating techniques.

One such technique relies on the fact that the position of the magnetic poles has changed over time; with magnetic north wandering from Northern Europe around 1,000 AD, eastwards across Siberia to a circular trip around the northern Pacific Ocean around 1,300 AD, skirting back past the North Pole around 1,600 AD then around the north-eastern corner of the North American continent and back towards the North Pole around 1,900 AD. Because baking fixes iron particles facing the magnetic poles at the time of firing, pottery can be dated by referring to an index of the known positions of the poles.

Another, widely used, technique is known as thermoluminescence. This relies on the fact that some of the impurities baked into pottery are radioactive. By reheating pottery samples a faint light, or luminescence, is emitted. Measuring this light it is possible to obtain a precise age.



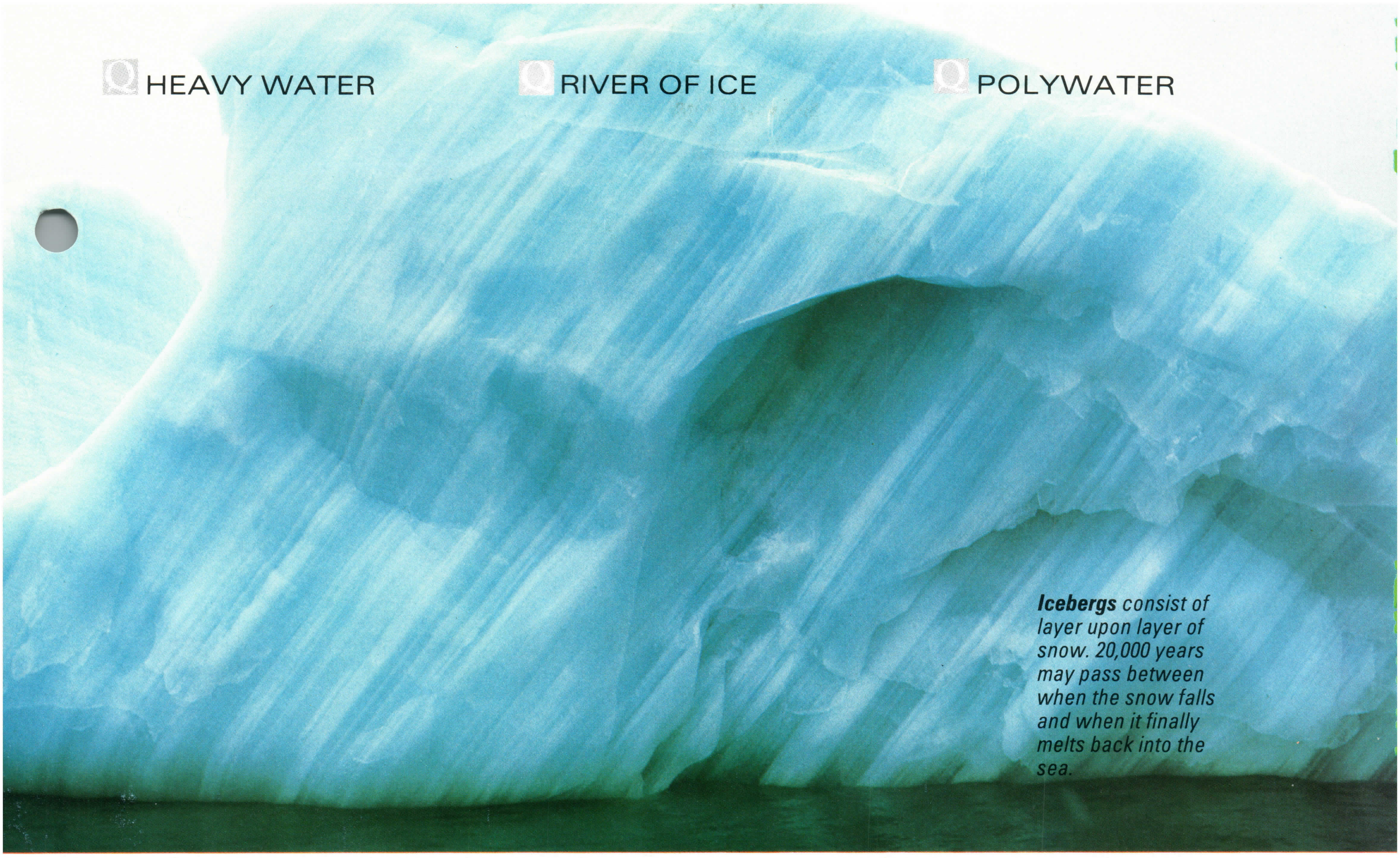
John Houghton

P Morris

Cosmic rays

Measuring the amount of carbon-14 in dead vegetable matter can reveal approximately how long it is since the plant died – some allowance has to be made for possible changes in the amount of carbon-14 in the atmosphere in the past. Such changes occur when the amount of cosmic radiation bombarding the atmosphere alters – associated with increases in sunspot activity.

The half-life of carbon-14 is 5,730 years. Using this fact some rock deposits dating from the last ice age, which ended 10,000 years ago, have been dated by plant matter found in the rocks. Human beings, physically essentially the same as modern people, were flourishing then. Items such as cloth of papyrus, can be dated by the carbon-14 method. Several different radioactive dating methods are used, enabling scientists to piece together the puzzle of the Earth's history.



***Icebergs** consist of layer upon layer of snow. 20,000 years may pass between when the snow falls and when it finally melts back into the sea.*

Tony Stone Photo Library, London

FANTASTIC FLUID

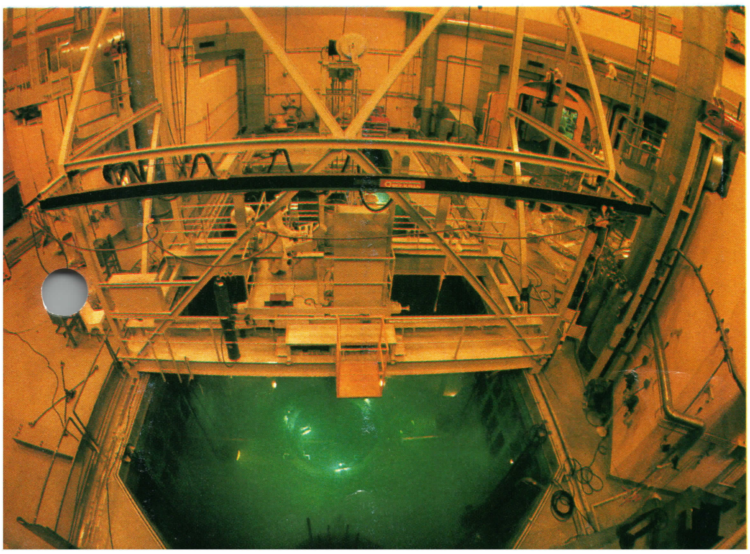
THERE IS NO SUCH THING AS ordinary water – every drop is extraordinary. Among other things, it's the only everyday substance that exists in all three physical states of matter – solid (ice), liquid (water) and gas (water vapour).

Even the supposedly pure liquid that you drink every day is a mixture of two completely different types of water – light water plus very small amounts of heavy water. The heavy variety weighs 10 per cent more than the same amount of ordinary water and so you would have no difficulty floating in a bath of it.

Two atoms of hydrogen and one atom of oxygen combined together form water. But the hydrogen in heavy water is very different from ordinary hydrogen.

The nucleus of an ordinary hydrogen atom contains one proton. When the nucleus also contains a neutron, the atomic mass is doubled and the atom becomes the heavy isotope of hydrogen called deuterium, which makes heavy water.

Heavy water is used in atomic reactors to slow down neutrons and so control the amount of heat produced. Some atomic reactors are also filled with heavy water to ensure easy access to the uranium fuel rods without allowing the escape of radioactive particles.



ZEFA

***Atomic reactors** are sometimes filled with heavy water. This is ten per cent heavier than ordinary water. Heavy water slows down any neutrons passing through it and is often used as a radiation shield around reactors to protect the people working on them from radioactivity.*

Strange behaviour

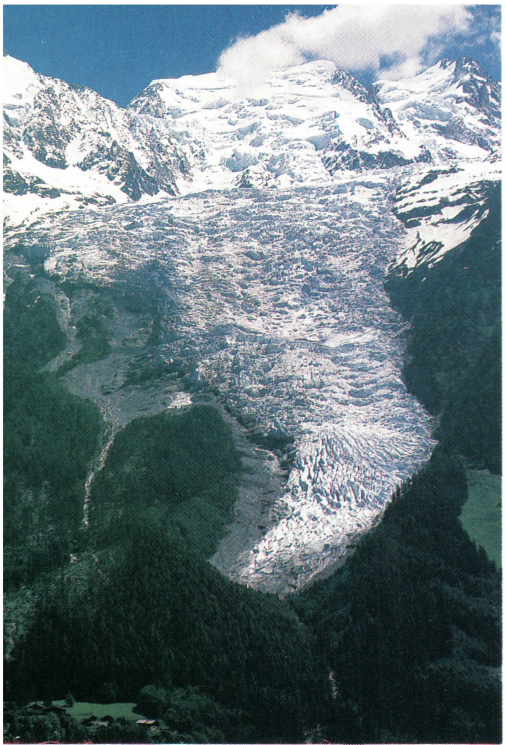
Water is also just about the only substance in the world that ever expands – gets larger – as the temperature falls. Nearly everything else contracts – gets smaller – as this happens. It works like this.

Water behaves normally and contracts down to a temperature of 4°C. If the temperature falls below that, water expands until it reaches 0°C. Water normally turns into ice at that point and expands again.

If a rare substance like gold behaved like this, it wouldn't really matter. But as three quarters of the Earth's surface is covered with water and all living things need it to stay alive, the strange behaviour of water is very significant.

Warm bottom

Indeed, lots of animals that live in water owe their very existence to the fact that water is at its heaviest at 4°C. When it falls below that temperature, water floats to the surface, so ice always forms on the surface of a pond or the surface of the sea. It doesn't form at the bottom as you might expect from



***Glaciers** rip chunks out of the underlying rock. When a glacier melts, this rock is dumped at the bottom of the mountain.*

the way that other liquids behave.

As a result, the water at the bottom of a pond stays at 4°C. Fish and other marine animals live out the cold weather in this warm layer and normally survive until the ice above melts and everything goes back to normal. They only get frozen, and so die, if the water freezes solid right through.

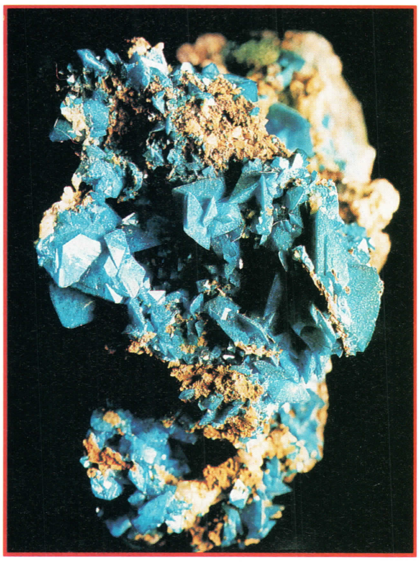
Burst pipes

This is fine for the fish, but the way that water expands when it freezes can create problems. Nine litres of water expands into ten litres of ice and the forces behind this are immense. The thin copper pipes that carry drinking water around your home simply can't stand up to the pressure and they burst. When the temperature rises, the ice in the pipe melts and water pours out.

Water also absorbs an unusually large amount of heat before it boils. This makes it very good for transmitting heat around a house via the central heating system and for cooling things like car engines. But car engines and radiators can burst in the same way as water pipes if the water freezes.

The way round this is to add ethylene glycol – antifreeze – to the water in the radiator. This freezes at –13°C and so reduces the temperature at which the engine freezes.

In fact any impurity added to water affects its freezing and boiling point. So when your local council spreads salt on icy roads, it lowers the freezing point of the water and melts the ice. When salt is added to water during cooking, it raises its boiling point and the food cooks faster.



Simon Fraser/SPL

Geoscience Features Picture Library

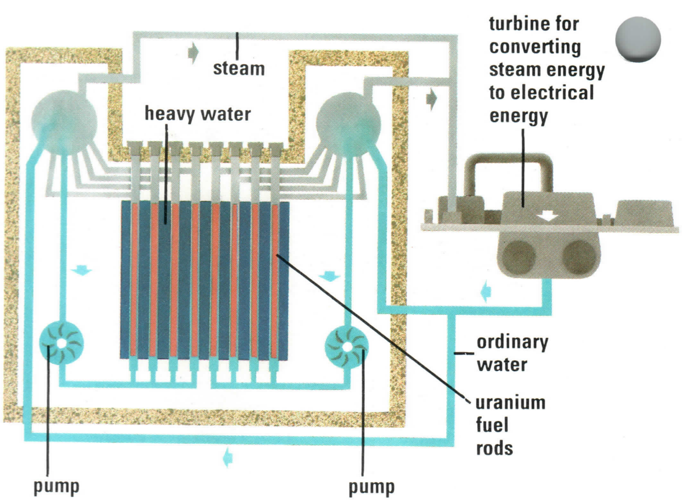
***Liroconite** like many other crystals, contains molecules of water locked up in the lattice structure of the crystal.*

ON THE EDGE

The edge of a skate blade is not a knife edge but is about 3 mm wide, so an adult weighing 60 kg generates a pressure of 8 kg per square centimetre at the point where the blades touch the ice. The pressure melts the ice under the skate blade and so a film of water is created between the blade of the skate and the ice. This film lubricates the passage of the skate over the ice and allows a skater to whizz around the ice with the greatest of ease. The water film freezes over when the pressure of the skate edge is removed. If there are a great number of skaters on a rink, the ice can start to melt.

Under pressure

The boiling point is also affected by air pressure. Car cooling systems take advantage of this by having a working pressure up to a third higher than atmospheric pressure. Inside the radiator, water does not boil until the temperature goes over 110°C. But if you undo the radiator cap while the engine is hot, the pressure inside the radiator goes back to normal and the cooling water immediately boils. Following this, a jet of hot water at about 110°C erupts out of the radiator.



***Uranium fuel rods** in nuclear reactors generate neutrons which are slowed by the surrounding heavy water. The heavy water level controls the amount of steam generated.*

UKAEA/Janos Marffy

Keeping cool

By running the cooling system at a high pressure and temperature, car designers can use a smaller radiator than would be required if the cooling system operated at normal atmospheric pressure.

On the other hand, reduced air pressure has the effect of reducing the boiling point of water. At ordinary altitudes, this has little effect. But in the high mountains, cooking

Atomic Energy of Canada

***Heavy water** plants are built at electricity generating stations because the process of separating heavy water from light water takes an enormous amount of electricity. Most heavy water is used to control – moderate – the amount of heat produced by atomic reactors. It is mostly produced in Canada where electricity is cheap.*

David Rootes/Planet Earth Pictures

***Sea ice** covers large areas of the polar regions during winter, but life goes on underneath. If water froze from the bottom up, aquatic animals would eventually become trapped on the surface of the ice with an insufficient depth of water to keep them alive and no way of escape.*

is very difficult and slow because water boils at around 70°C and so doesn't heat the food enough to cook it.

Below 0°C, water normally becomes a solid but if you scoop up a handful of snow and mould it together with your hands, a little of the snow melts and sticks the ice crystals together into a snowball. So pressure reduces the temperature at which water freezes into ice.

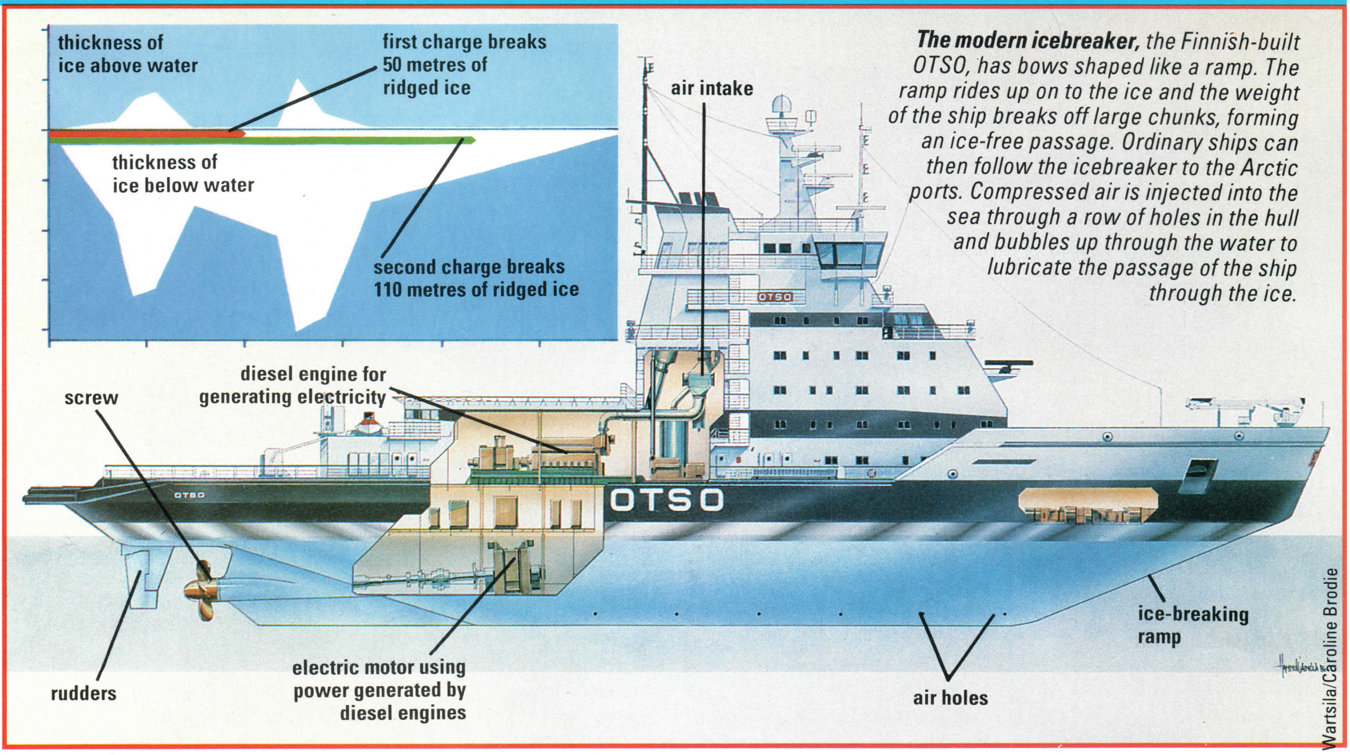
When snow falls on a mountain, it builds up until the weight squashes the air out of the bottom layers. So much pressure is applied to the bottom layers that sheets of apparently solid ice move at speeds of up to about 19 metres per day.

Where the shape of the underlying land funnels the ice downhill, it becomes a river of slowly moving ice known as a glacier. At the bottom of the mountains, the glacier melts and becomes a river of ordinary but very cold water.

Parts of the polar ice caps are also glaciers – one Antarctic glacier is 400 km long. At the low polar temperatures, a glacier doesn't melt but keeps on going until it sticks out into the sea. At intervals the end then breaks off under its own weight and forms icebergs.

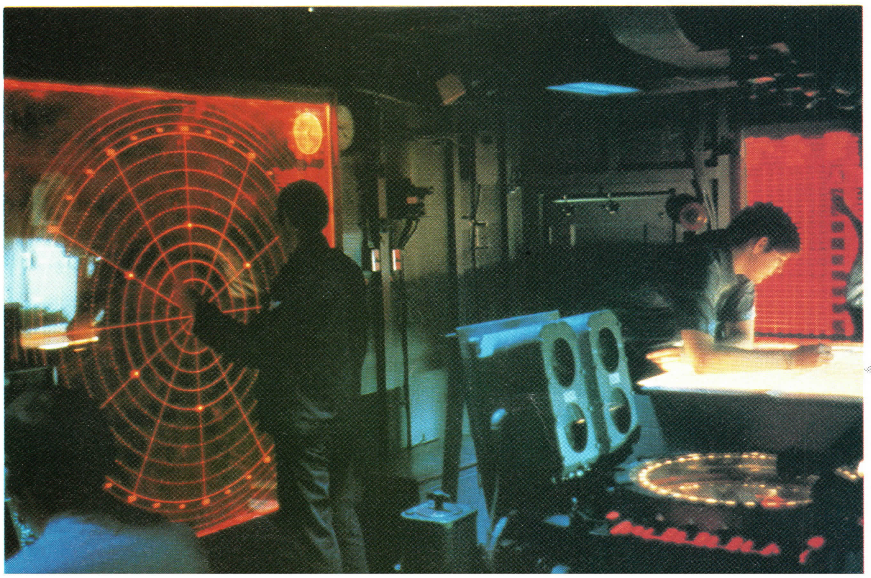
Some icebergs are only ten or fifteen metres across and are known as growlers because of the noise that they make when they rub against each other. On the other hand, the largest iceberg ever sighted was larger than Belgium. Another was tracked for 17 years before it finally melted away.

DIESEL-ELECTRIC ARCTIC ICEBREAKER



***The modern icebreaker,** the Finnish-built OTSO, has bows shaped like a ramp. The ramp rides up on to the ice and the weight of the ship breaks off large chunks, forming an ice-free passage. Ordinary ships can then follow the icebreaker to the Arctic ports. Compressed air is injected into the sea through a row of holes in the hull and bubbles up through the water to lubricate the passage of the ship through the ice.*

Wartsila/Caroline Brodie



Frank Spooner Pictures

***Submarine navigation** stations are dominated by enormous cathode ray tube (CRT) sonar displays. The positions and range of all nearby ships are displayed so that the submarine commander can plan his route through the escort ships, make his attack and escape.*

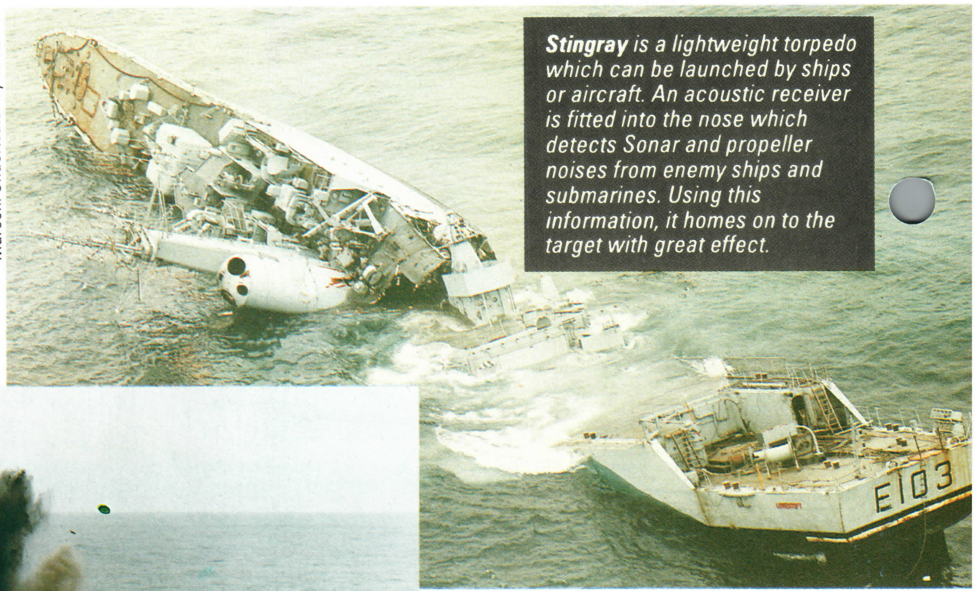
Towing icebergs

Ice is lighter than the water it floats in, so only one-ninth of the height of an iceberg shows above the surface. An iceberg stretching 60 metres above the water actually extends 480 metres below.

Many ideas of using these chunks of frozen water have been dreamed

up and some may eventually be used. The most popular one is the notion of towing icebergs to areas that are desperately short of fresh water like the Persian Gulf. Once there, the bergs will melt in the sun and the water will be collected for drinking. The water in icebergs is so pure that it is entirely safe for drinking.

Another idea is to mix ice with wood shavings to form a material called pikecrete. Icebergs would supply the raw material and a raft of Pikecrete could be towed anywhere to serve as an artificial harbour or emergency landing strip in mid-ocean. A freezer unit built on the deck of the pikecrete raft would prevent it melting.



Marconi Underwater Systems

__Stingray__ is a lightweight torpedo which can be launched by ships or aircraft. An acoustic receiver is fitted into the nose which detects Sonar and propeller noises from enemy ships and submarines. Using this information, it homes on to the target with great effect.

Marconi Underwater Systems/TRH

At the swimming baths, you may have noticed that you can hear all sorts of strange sounds through the water. In fact sound travels hundreds of times further through water than through air. Taking advantage of this, all submarines and most surface warships are equipped with Sonar, which is short for Sound Navigation And Ranging.

A high-pitched pulse of sound is sent out into the water by the Sonar apparatus. This pulse bounces back off anything solid, such as surface ships or other submarines, so the echoes can be picked up by an underwater microphone. This is very similar in principle to radar.

Echoes

The returning echoes are distorted as they pass through the different layers of the ocean – layers formed by water of different temperatures and saltiness. To eliminate some of this distortion, the echoes are processed electronically. The time taken for the sound to reach the other vessel and return indicates how far away the other vessel is. The resulting information is then presented on a screen so the commander can plan his attack.

Propeller noises also travel enormous distances through water. To combat this, warship and submarine propellers are carefully designed to minimise the noise that they create and to make as few bubbles as possible. Highly sophisticated machine tools are required to cut the complicated shapes of these low noise naval propellers.

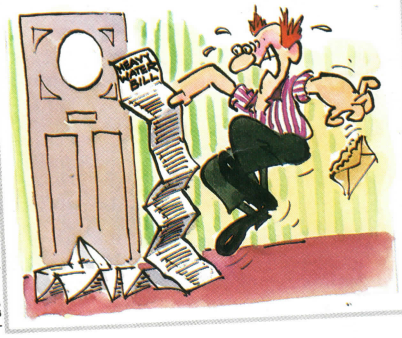
Not content with all these strange properties, scientists have come up with the theoretical possibility that one day, water molecules might start to behave like polythene molecules and join together – polymerise – into long chains. This Polywater would absorb all ordinary water. You could drink as much Polywater as you liked but it wouldn't quench your thirst or keep you alive.

Marconi Underwater Systems

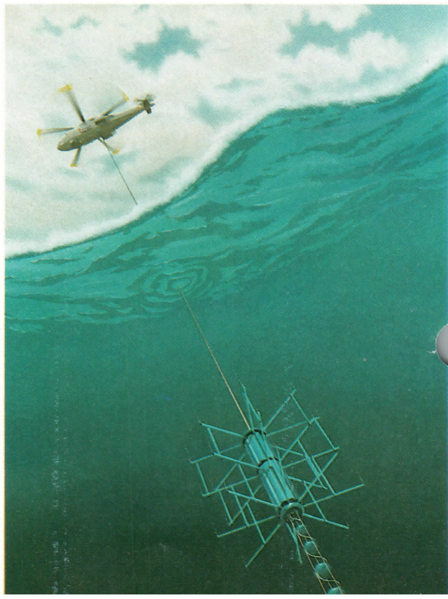
Just amazing!

MONEY DOWN THE DRAIN

IF YOU USED HEAVY WATER INSTEAD OF TAP WATER FOR WASHING, FLUSHING THE TOILET AND MAKING THE TEA, YOUR ANNUAL WATER BILL WOULD BE OVER £10,000,000!



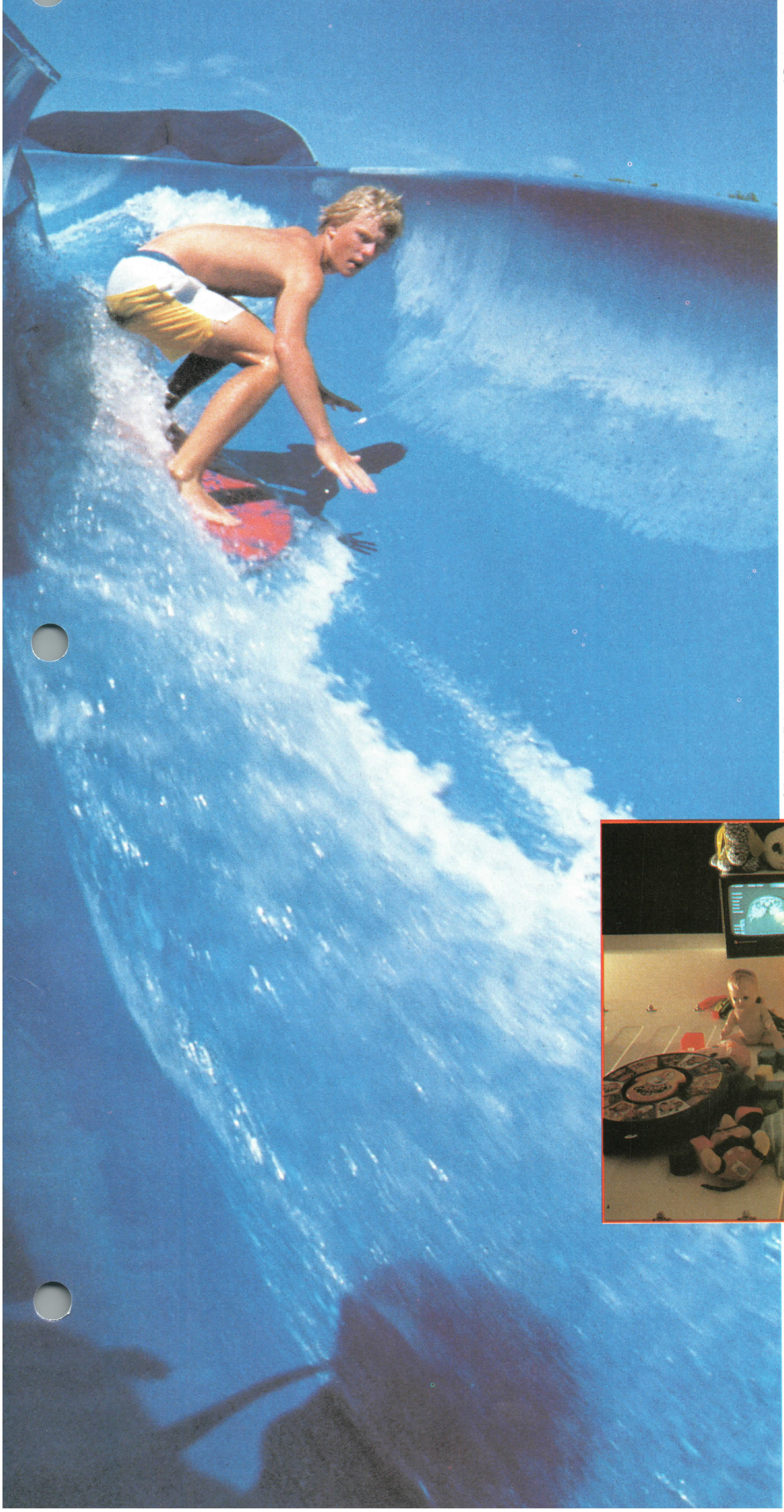
Paul Raymonde



British Aerospace/T

__Dipping sonars__ are carried by helicopters and enable them to search large areas of water for submarines. This type of Anti-Submarine Warfare (ASW) equipment is more effective than ship-borne Sonar because of the helicopter's speed and range, which allow it to search waters well ahead of the fleet.

TAKING THE PLUNGE



J Budge/Liaison/Frank Spooner Pictures

- HEALING BATHS
- SWIMMING FOR HEALTH
- WATER THEME PARKS

WATER IS PROBABLY THE oldest medicine known to Man. Hippocrates, the father of modern medicine, used water and thermal springs to treat the sick of ancient Greece. Centuries later the ancient Egyptians worshipped the Nile for its apparent healing properties.

When used correctly and on specific parts of the body there is no doubt that water has a great healing value. It can be used either hot or cold. The different temperatures have different effects on the body. Each effect has a short, initial action which is followed by a more prolonged, secondary one. Furthermore, warm and cold water have very different actions.

Ice bag

In medicine these actions are used to treat many different conditions. For example, if you twist your ankle playing sport – an acute, or sudden, injury – the aim is to stop

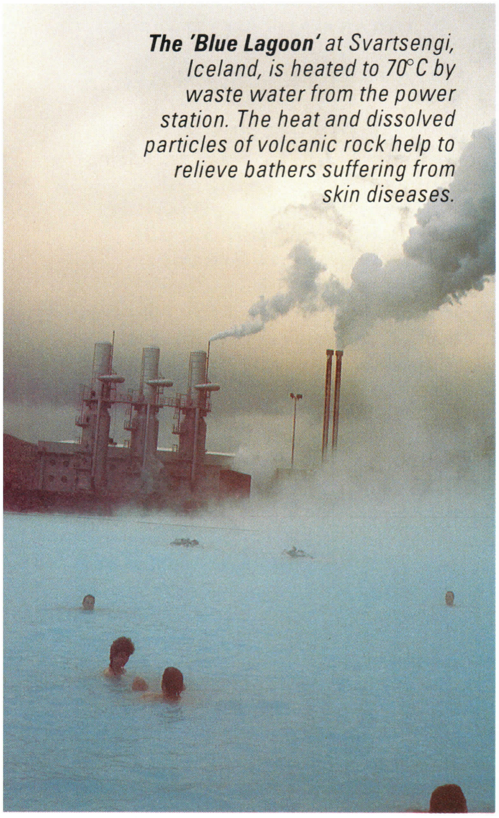
Alexander Tsiaras/SPL

***A tent of warm water** covered by a thin plastic membrane lulls a baby undergoing an ultrasound scan of his kidneys.*

***A slide surfer,** surfing down a water slide at Florida's Wet & Wild water theme park takes water thrills and spills to their limits.*

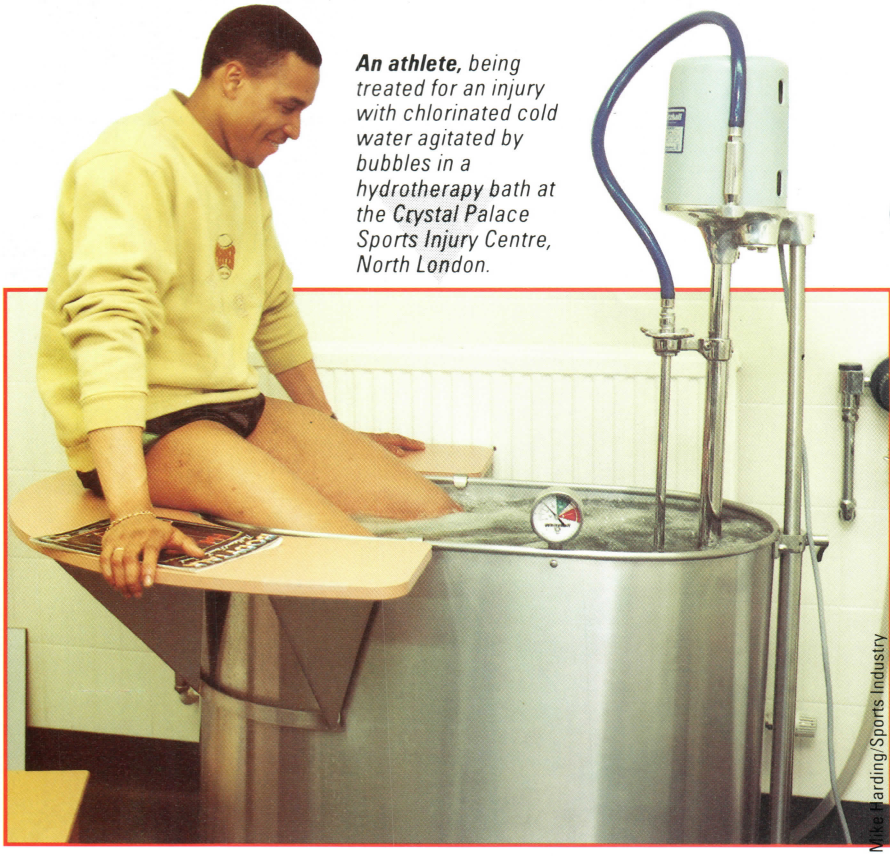
the pain and reduce the swelling as soon as possible. Here you would use cold water in some form. Ice is best, although it should never be applied directly to the skin because it would stick and 'burn'.

A bag of frozen peas is ideal, but a cold towel or even a cold can of soft drink can just as easily be used. Place the cold pack over the damaged area for at least 15 minutes; this allows the secondary effects to take place (see HOT AND COLD WATER PACKS).



***The 'Blue Lagoon'** at Svartsengi, Iceland, is heated to 70°C by waste water from the power station. The heat and dissolved particles of volcanic rock help to relieve bathers suffering from skin diseases.*

Simon Fraser/SPL



***An athlete,** being treated for an injury with chlorinated cold water agitated by bubbles in a hydrotherapy bath at the Crystal Palace Sports Injury Centre, North London.*

Mike Harding/Sports Industry

If you have a long-standing injury (a chronic condition) it is best to use alternate hot and cold water. Normally towels, soaked in hot and cold water, are applied directly to the damaged area, but a shower hose may be more convenient. The hot water relaxes the area and brings blood to it. The cold water kills the pain and 'flushes' the area with fresh blood. The overall effect is pain-killing, relaxing and healing.

Bath time

Water treatment, or hydrotherapy, can take many forms. The most common are:

- Full immersion cold bath – this is used to help control fevers (only under specialist advice and control)
- Full immersion hot bath – this is used for a short time only (2–10 minutes) to treat poor circulation
- Water jets (douches) – these are used locally or generally over the body. They are best used with alternating hot and cold sprays – hot for 3 minutes, cold for 1 minute. They work in the same way as hot and cold packs but are more stimulating and have a stronger effect
- Epsom salt (magnesium sulphate) bath – similar to the hot immersion bath but epsom salts are added to the water. This relaxes tight muscles, and is particularly good after a strenuous exercise.

Hot springs

Many people with joint and muscle pains claim great relief after bathing in natural hot springs or pools. These are kept hot by the 'geothermal' heat generated within the Earth's crust.

The healing effects of hot springs were noted by an Italian-American man called Roy Jacuzzi who built a bath that artificially created the effects of a hot spring pool for his

FITNESS PROGRAMME

Swimming is excellent for the healthy body, exercising not only the joints and muscles but working the heart and lungs. The three main strokes work the following muscles: crawl and backstroke work shoulder, chest, upper back, and legs; and breaststroke works chest, upper back, shoulders, arms, neck and legs.

You must have at least the elementary swimming certificate before attempting this programme.

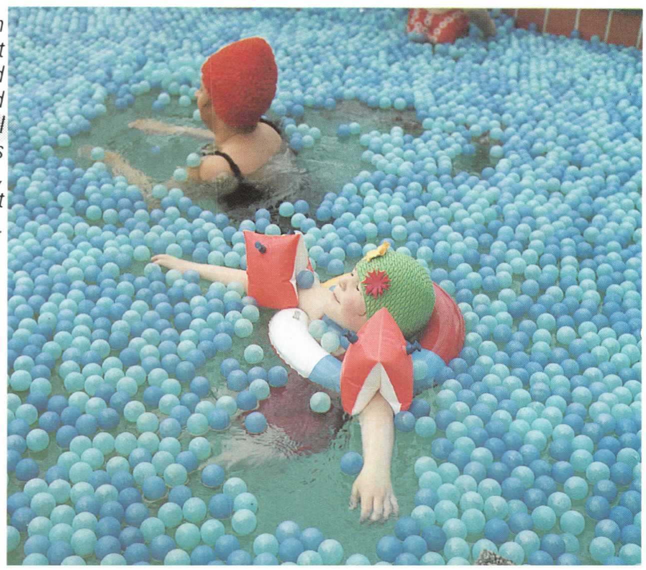
Week One: 1 length crawl, 1 length backstroke, 1 length breaststroke. Aim to swim about 12 length (400 metres).

Week Two: 2 lengths crawl, 2 lengths breaststroke, 2 lengths backstroke. Aim to swim about 24 lengths (600 metres).

Week Three: As in week two.

Week Four: 3 lengths crawl, 3 lengths breaststroke, 3 lengths backstroke. Aim to swim about 36 lengths (1,200 metres) in total.

Never push yourself. If you feel tired STOP and REST and NEVER try to swim through muscle cramp or stitch.



***A thermal bath** in Ruhpolding, West Germany is enjoyed by young and old bathers. The small plastic balls act as an insulation, helping to stop heat escaping.*

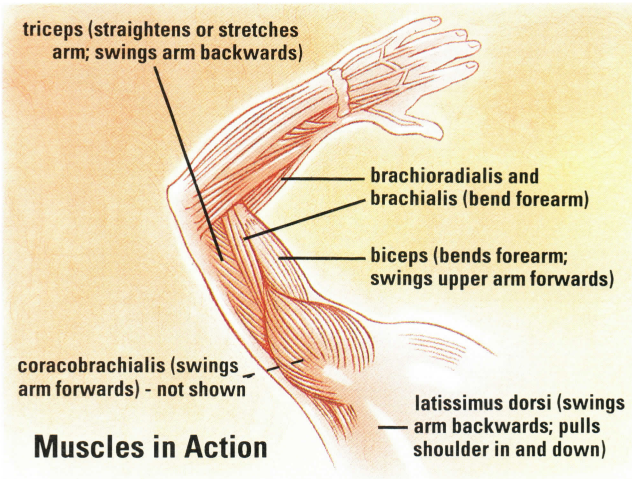
ZEFA

Tony Stone Photo Library, London

son who suffered with rheumatism. This bath, as well as containing hot water, also produced many jets of bubbly water. The hot water relaxed the muscles and soothed joints, while the jets massaged the arms, legs and back. The idea soon caught on and the Jacuzzi, as it became known, is now widely used for both therapy and relaxation.

One of the best therapeutic uses of water is swimming. In a swimming pool your body is supported by the water and the stress and strains of gravity are removed from your joints. This produces great relief for people with joint disease or injury. If combined with gentle exercise, a very effective rehabilitation therapy is created for both the old and people with joint and muscle disease. This type of hydrotherapy is used in hospitals by physiotherapists every day.

Swimming works nearly every muscle in the body as well as the heart and lungs. In the front crawl, the main muscle groups worked (right) are those of the arms, shoulders and legs.



Mark Iley

Water theme parks, such as Wet & Wild in Florida, USA, are designed to provide safe thrills and spills for water daredevils.

Wet'n Wild

Water fun

Water is not only used for fitness and therapy – it can also be great fun. This element has been exploited in water theme parks. In places such as 'Aquapark' on Spain's Costa del Sol and Florida's 'Wet and Wild', rides are constructed that aim to use both height and water to create safe thrills and spills.

Excitement

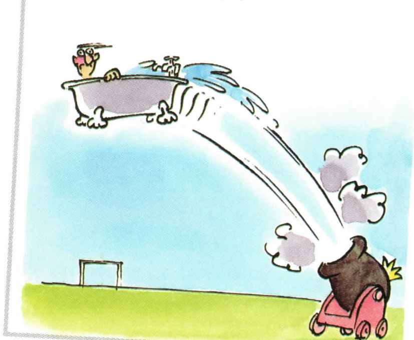
When you feel excited your heart pounds, breathing becomes rapid and you feel trembly. This is because your body produces a hormone called adrenalin. This hormone is made at times of stress to prepare your body to fight or run. When you are at the top of a water ride, about to plunge downwards your body releases lots of adrenalin in response to the fear of the sudden drop and you feel excited.

Water is very hard if you land on it awkwardly in a painful bellyflop. This is because the molecules of water are packed very closely together. A feature of some water theme parks is the bubble pool. In it thousands of bubbles are pumped into the water to break up the hard surface. This means that you can land in the water any way that you want, jumping in wildly or performing outrageous bellyflops, without hurting yourself.

Just amazing!

HARD WATER

A WATER CANNON THROWS MORE THAN FOUR BATHFULS OF WATER EVERY SECOND WITH ENOUGH FORCE TO KNOCK YOU OFF YOUR FEET AT THE OTHER END OF A FOOTBALL PITCH.



PROFILE HOT AND COLD WATER PACKS

COLD WATER

Initial effect
- Small blood vessels contract
- Skin becomes pale
- Shivering and some discomfort
- Sensation of chilliness
- Stimulation of nervous system

Secondary, longer lasting, effect
- Small blood vessels dilate
- Skin turns red
- Pain relief, relaxation and comfort
- Sensation of warmth
- Relaxation of nervous system

WARM WATER

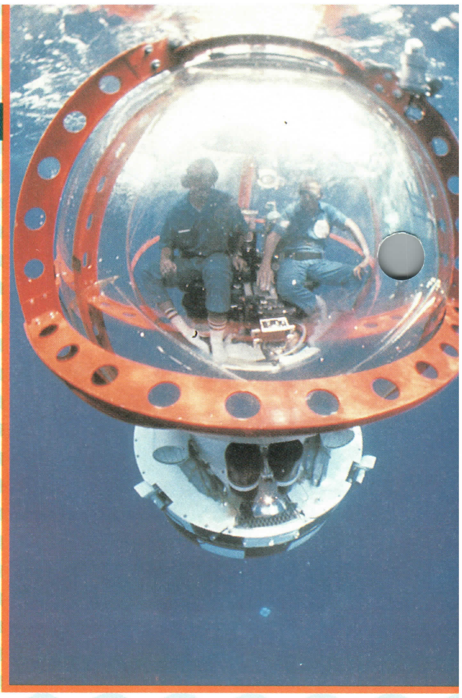
- Expansion of small blood vessels; blood rushes to area
- Stimulation of nervous system
- Muscular discomfort
- Extra amounts of blood are drawn into injured area
- Tiredness and drowsiness
- Muscular weakness and relaxation

ZEFA

Quadrant Picture Library

The swamp buggy, *is a flat-bottomed craft, powered by an aircraft propeller, specially designed to cope with the Everglades of Florida. They are also raced.*

The clear sphere *of the US Navy's N.E.M.O. – Naval Experimental Manned Observatory – provides an ideal view of life beneath the sea.*



Flip Schulke/Planet Earth Pictures

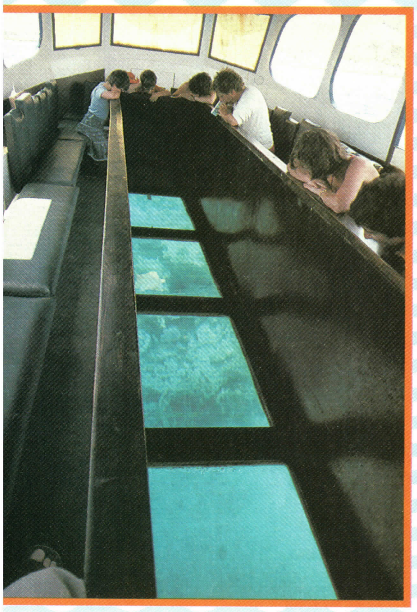
Grey Iveco, *an offshore power boat taking part in the British Cowes – Torquay – Cowes race, has two 10 litre, turbocharged diesel truck engines, producing 1200 hp and can reach speeds of 144 km/h.*

A glass bottom boat, *here on the Red Sea in Israel, is one of the best ways to observe life beneath the sea without getting your feet wet. Renowned for its clarity, the Red Sea is highly prized by sporting divers and marine biologists.*

Tony Stone Photo Library, London

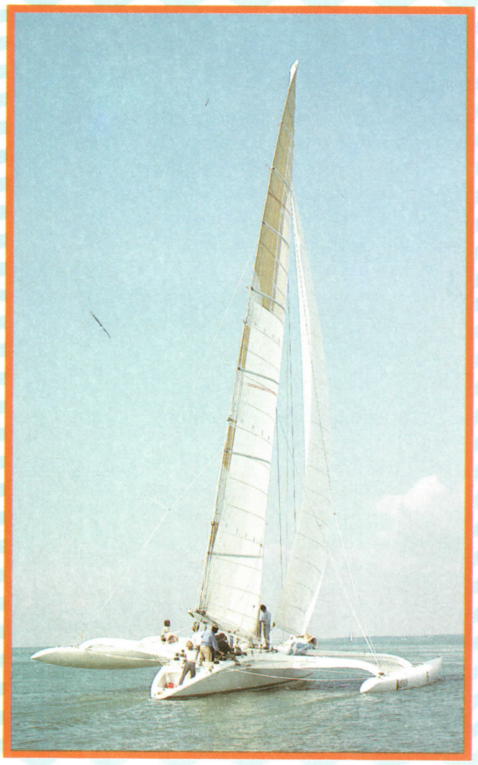
A tandem windsurfer *is one of the fastest sailing craft around, providing a large sail area with low weight and little water and air resistance.*

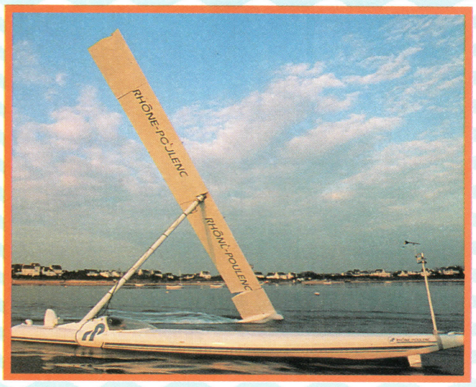
This strange craft *is the latest in sailing technology, employing a wing rather than the more conventional sail to capture the aerodynamic force normally used to drive a sailing vessel.*



John Lythgoe/Planet Earth Pictures

A racing trimaran *is able to carry an extremely high area of sail without capsizing due to the support provided by the balancing outrigger hulls.*





Philip Plisson/Allsport

Jet skis, *normally powered by 650 cc motorcycle engines, are capable of speeds up to 70 km/h and are steered like a motorcycle.*

Gamma Frank Spooner Pictures